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Cost analysis of a transition to green vehicle technology for light duty fleet vehicles in Public Works DepartmentNaval Support Activity Monterey (PWD Monterey)

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

COST ANALYSIS OF A TRANSITION TO GREEN VEHICLE TECHNOLOGY FOR LIGHT DUTY FLEET VEHICLES IN PUBLIC WORKS DEPARTMENT–NAVAL SUPPORT ACTIVITY MONTEREY (PWD MONTEREY)

December 2015

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13. ABSTRACT (maximum 200 words)

The MBA Project is a detailed cost analysis of various mature green vehicle technologies that can be implemented by Public Works Department–Naval Support Activity Monterey (PWD Monterey) and its subordinate entities, with the intent of reducing both overall life-cycle vehicle costs and carbon emissions. The focus is on light-duty, non-tactical vehicles in use in the region. The cost analysis explores Plug-In Hybrid Electric Vehicles (PHEV), the infrastructure required to operate them, and the social cost of carbon emissions (SCC).

Our model indicates that it is not economically beneficial to implement green vehicle technologies on a fleet-wide level for PWD Monterey. Although there are SCC benefits, and right-sizing fleet vehicles to suitable alternatives leads to savings, the increased cost of PHEVs and relatively large required infrastructure cost outpace the total benefits.

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LIST OF ACRONYMS AND ABBREVIATIONS

1GW TF – 1 Gigawatt Task Force

2WD – two wheel drive

4WD – four wheel drive

AFDC – Alternative Fuels Data Center

AFV – alternative fuel vehicle

AOR – area of responsibility

AVTA – Advance Vehicle Testing Activity

BBL/DAY – barrels per day

BEV – battery electric vehicle

CO_2 – carbon dioxide

DASN – Deputy Assistance Secretary of the Navy

DOD – Department of Defense

DON – Department of the Navy

EIA – Energy Information Administration

EO – executive order

EPA – Environmental Protection Agency

EVSE – electric vehicle supply equipment

FAST – Federal Automotive Statistical Tool

FCEV – fuel cell electric vehicle

FFV – flexible fuel vehicle (flex fuel)

FY – fiscal year

GHG – greenhouse gas

GSA – General Services Administration

GVT – green vehicle technology

HD – heavy duty

HEV – hybrid electric vehicle

IAW – in accordance with

ICE – Internal Combustion Engine

INEL – Idaho National Energy Laboratory

JBLM – Joint Base Lewis-McChord

LCC – life cycle cost

MPH – miles per hour

NAS – Naval Air Station

NAVFAC – Naval Facilities Engineering Command

NEV – neighborhood electric vehicle

NS – Naval Station

NSAM – Naval Support Activity Monterey

NTV – non-tactical vehicle

PEV – plug-in electric vehicle

PHEV – plug-in hybrid electric vehicle

PWD – Public Works Department

SCC – social cost of carbon

SECNAV – Secretary of the Navy

SUV – sport utility vehicle

U.S. – United States

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I. INTRODUCTION

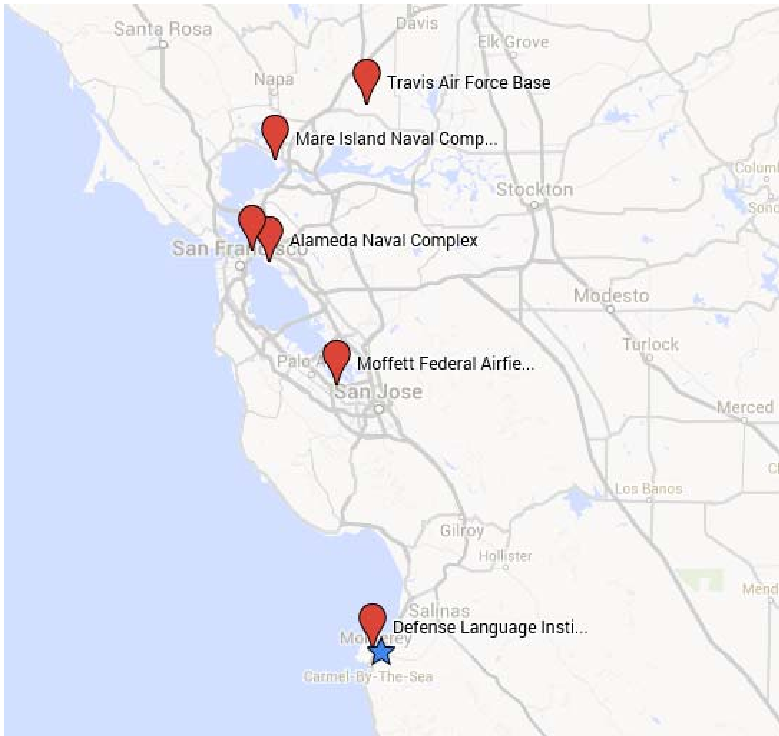
A. SCOPE AND LIMITATIONS

This MBA project provides a detailed cost analysis of replacing the current light duty non-tactical vehicles at Naval Facilities Engineering Command (NAVFAC) Southwest–Public Works Department (PWD), Naval Support Activity (NSA) Monterey with various plug-in electric vehicles available through General Services Administration (GSA) and on the open market. The project determines if replacing PWD Monterey's current vehicle fleet with plug-in electric vehicles (PEVs) is economically feasible and will result in a life-cycle cost (LCC) and carbon emissions benefit.

The two PEVs primarily covered in this study are: (1) Battery Electric Vehicles (BEVs) and (2) Plug-In Hybrid Electric Vehicles (PHEVs). BEVs are powered solely by battery while PHEVs are powered by both battery and gasoline. A more detailed description of these two alternatively-fueled technologies can be found in the background section of this study.

Currently, PWD Monterey's light duty fleet consists of 87 vehicles (14 sedans and 73 trucks and cargo vans). These vehicles are used at NSA Monterey and six other military installations throughout the San Francisco bay area, shown in Figure 1, including Alameda Naval Complex, Treasure Island, Defense Language Institute (DLI), Mare Island Naval Complex, Moffett Federal Airfield, and Travis Air Force Base.

Figure 1. PWD Monterey Area of Responsibility



PWD Monterey and the San Francisco Bay area bases for which it holds fleet vehicle responsibility. Source: My Maps. (2015). Retrieved October 15, 2015, from Google Maps: www.google.com/maps/d/edit?hl-en&authuser=o&mid=zp6dy-Bopv0.kpvsl0iy8Wme

PWD Monterey has overall jurisdiction of these vehicles, which are contracted through the GSA centralized vehicle leasing program. This program was established to relieve Federal agencies "from both the time constraints and administrative costs associated with independently entering into lease contracts" (Code of Federal Regulations [annual edition], 2015, p. 100). The lease agreements are for a maximum of 7 years or 60,000 miles, whichever milestone comes first. The monthly lease includes both maintenance and fuel costs.

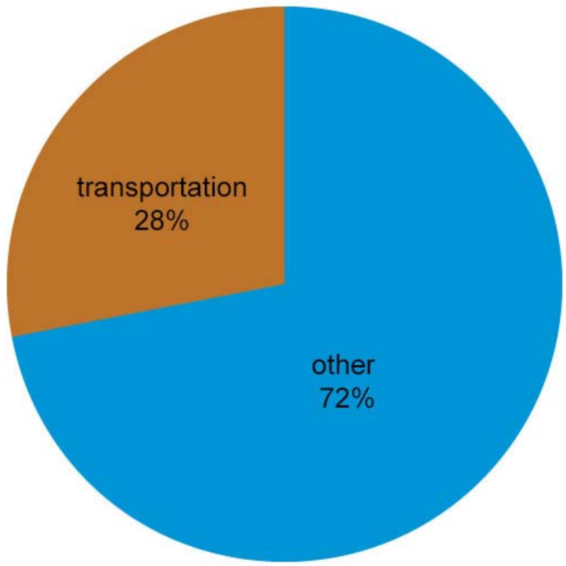
B. U.S./DOD OIL DEPENDENCE AND ITS IMPACT ON ENVIRONMENT

The following section discusses the United States and DOD's oil dependence within the transportation sector and how the emission of greenhouse gases (GHG) from this consumption impacts the environment.

1. Oil Consumption

In 2014, the United States' second leading sector in energy consumption came from transportation, roughly 28%. (U.S. Energy Information Administration, 2015). See Figure 2.

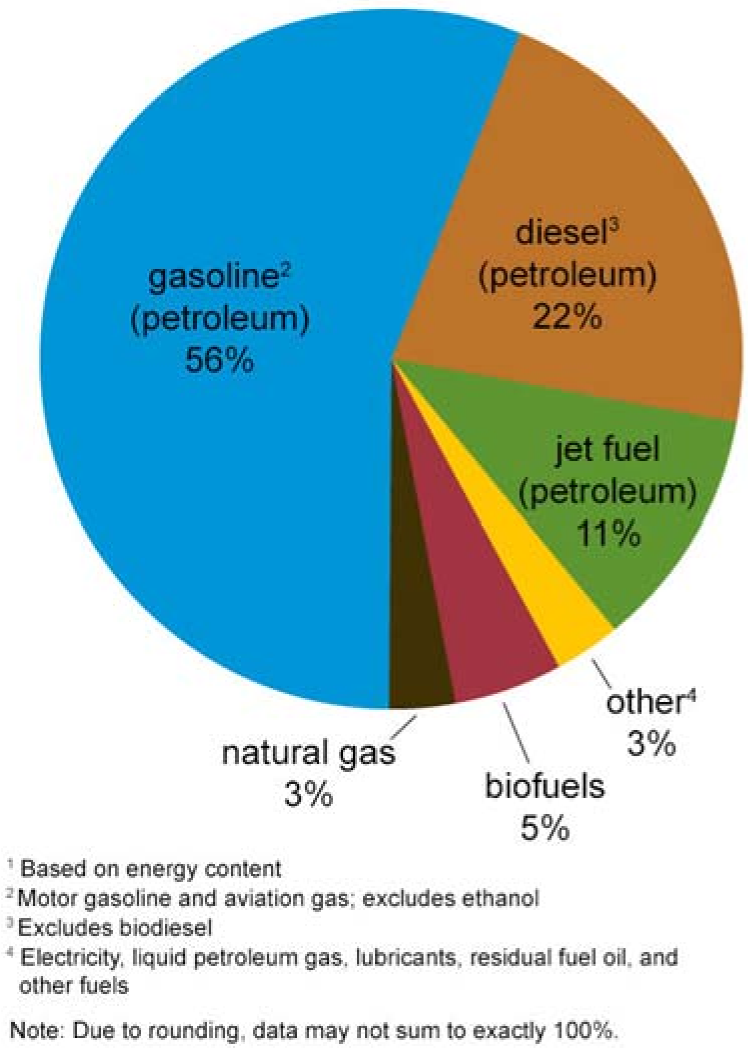
Figure 2. Share of Total U.S. Energy Used for Transportation, 2014.



Source: U.S. Energy Information Administration. (2015, July 17). Use of energy in the United States explained. Retrieved from U.S. Energy Information Administration: http://www.eia.gov/Energyexplained/?page=us_energy_transportation

Petroleum fuels are the main energy source within the sector. They make up approximately 92%, of which 56% is gasoline, as illustrated in Figure 3. Natural gas and biofuels comprise the remaining 8% of the fuels used in the sector.

Figure 3. Fuel Used for U.S. Transportation, 2014



Source: U.S. Energy Information Administration. (2015, July 17). Use of energy in the United States explained. Retrieved from U.S. Energy Information Administration: http://www.eia.gov/Energyexplained/?page=us_energy_transportation

The transportation gasoline consumption averages 8.8 million barrels per day (bbl/day), accounting for 40% of the world's daily gasoline consumption (U.S. Energy Information Administration, 2015).

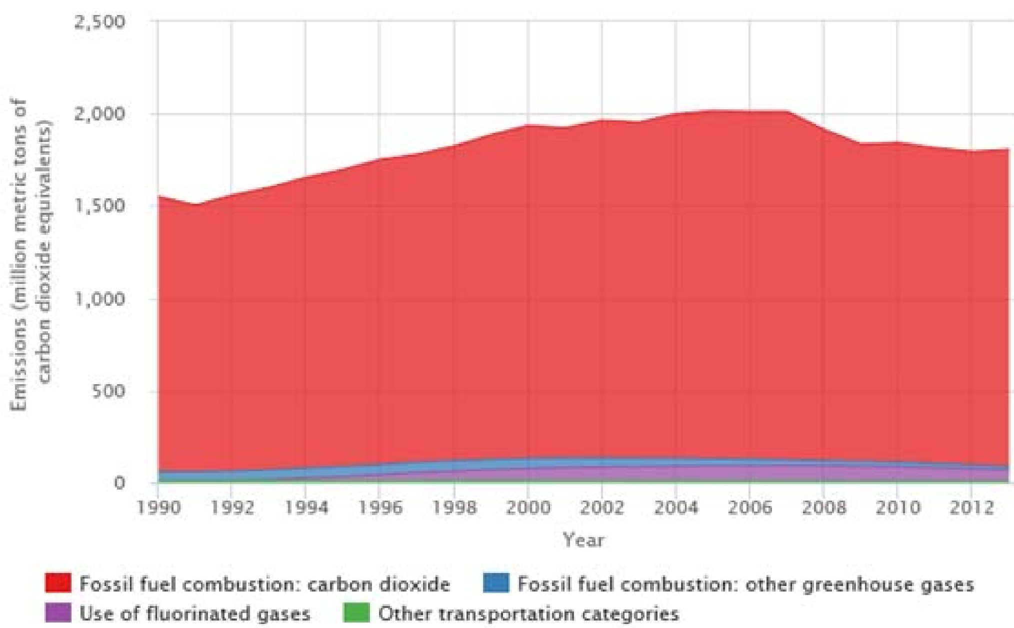
The Department of Defense (DOD) consumes approximately 300,000 bbl/day of oil, or 1.5% of the U.S. total petroleum consumption, making it the largest institutional oil consumer in the world (Chemi, 2014). To put the magnitude of this figure into

perspective, Nigeria's national daily oil consumption is 280,000 bbl/day for a population of over 180 million people (TheGlobalEconomy.com, 2015).

2. Impact on the Environment

The combustion of petroleum based products in internal combustion engines (ICEs) accounts for a majority of the carbon dioxide (CO_2) emissions in the atmosphere (EPA, 2015). Light-duty vehicles are the largest source of transportation-related GHG emissions, accounting for more than half of the emissions in the transportation sector (EPA, 2015). With the exception of a slight dip in 2007, GHG emissions have steadily increased since 1990, growing 16% in 23 years (Figure 4).

Figure 4. Annual U.S. Greenhouse Gas Emissions from the Transportation Sector, 1990–2013



Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990–2013, http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

The Intergovernmental Panel on Climate Change suggests that increasing concentrations of GHGs could have caused the temperature increases over the past 50

years. According to the EPA's *Environmental Impacts of Greenhouse Gases*, a warmer climate could lead to changes in:

- Rainfall patterns
- Polar icecap retreat
- Sea level rise
- Changes in ecosystems supporting human, animal and plant life
- Human health impacts
- Ocean acidification (Environmental Protection Agency, 2009).

Furthermore, the Environmental Protection Agency (EPA) uses the social cost of carbon (SCC) to estimate the economic impact related to an increase in GHG emissions, to include "changes in human health, property damages from increased flood risk, and changes in energy system costs" (EPA, 2015). We analyze SCC in our economic cost analysis.

C. FEDERAL MANDATES AND NAVY INITIATIVES

Over the last decade, the U.S. government has made a significant effort to increase energy efficiency and reduce the impact of GHG emissions from federal non-tactical vehicle fleets. This effort started when President George W. Bush signed the Energy Independence and Security Act of 2007, requiring an increase in the fuel efficiency of vehicles and a 20% reduction in gasoline consumption by 2015, using a FY 2005 baseline (U.S. Department of Energy, 2007). Two years later, President Obama signed Executive Order (EO) 13514, which increased the reduction standard to 30% by 2020 (Obama, The White House: Office of the Press Secretary, 2009). In February 2015, President Obama signed EO 13693, which requires a reduction in per-mile GHG emissions from the Federal fleets by 30% by 2025. It also mandates an increase in PHEV technology in all Federal fleets (Obama, 2015).

In October 2009, the Secretary of the Navy (SECNAV) published a *Shore Energy Policy* emphasizing what he saw as good energy stewardship in the military and set forth

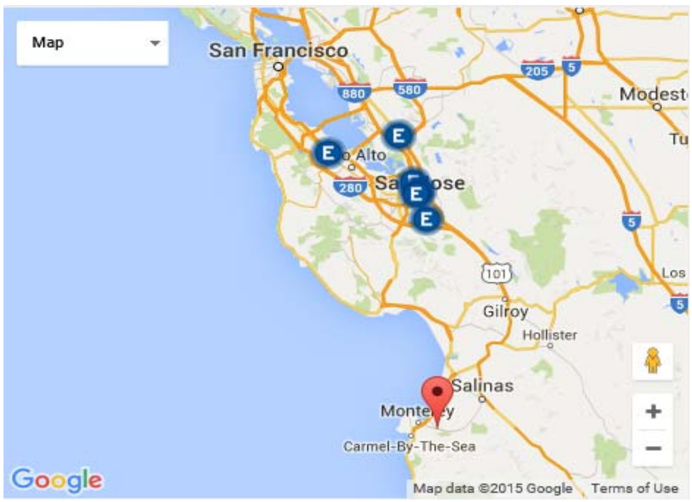
guidance to improve energy efficiency within the Department of the Navy (DON) (Hicks, 2011). One of the main goals of this policy was to reduce petroleum consumption by 50% in the Navy's non-tactical vehicle fleet by 2015 (Hicks, 2011). In order to accomplish this goal, SECNAV gave the following guidance pertaining to our study to the shore installations in the fleet in the *Shore Energy Policy*:

- Use alternative fuel 100 percent of the time:
    - Alternative fuel vehicles must be located in proximity to fueling stations with available alternative fuels and must be operated on the alternative fuel for which the vehicle is designed.
- Continue to right size the non-tactical fleet:
    - The standard sedan for the Navy is a compact alternative fuel vehicle.
    - Pickup trucks must be kept to the minimum size required to fulfill the vehicle mission. When vehicles are replaced the requirements must be examined to determine if a smaller vehicle can fulfill the mission.
        - 4x2 pickup trucks are the standard pickup. 4x4 must be justified by the agency fleet manager.
    - Gasoline vehicles must be replaced with alternative fuel, hybrid or electric vehicles where life cycle economical. In accordance with (IAW) the Presidential Memorandum on Federal Fleet Performance, by December 31, 2015, all new light duty vehicles leased or purchased must be alternative fueled vehicles.
- Reduce total vehicle miles traveled
- Performance monitoring
    - Progress toward this goal will be measured by the annual Federal Automotive Statistical Tool (FAST) data call. If the report indicates the Department of Navy is not on track to meet the goal, additional data calls may be conducted (Hicks, 2011, p.4-5).

One of the objectives that has been difficult for the Navy to comply with is the use of alternative fuel in the non-tactical vehicle fleet 100% of the time, simply because

the needed infrastructure has not been installed yet. For example, 83% of the vehicles in our study are trucks and vans. The current alternative fuel vehicle (AFV) options for trucks and vans within the DOD are flexible fuel vehicles (FFVs), which operate on E85 gasoline (85% ethanol, 15% gasoline, or a mixture of both). As illustrated in Figure 5, the closest ethanol gas station is located in San Jose, CA, which is 75 miles away from PWD Monterey, making it infeasible for PWD Monterey to use the designed E85 alternative fuel option.

Figure 5. Flex Fuel Stations in the PWD Monterey AOR



Source: Flex fuel station finder. (2015, November 4). Retrieved from Ethanol retailer website: http://www.ethanolretailer.com/flex-fuel-station-finder

D. ELECTRIC VEHICLES–AN ECONOMICAL SOLUTION?

Based on the federal mandates and directives from the Navy, we calculate the cost for transitioning the selected light duty vehicles at PWD Monterey to PEV technology, on a per mile, per month, SCC, and total basis (to include fuel and maintenance costs). This report provides comparisons to a traditional ICE and provides a recommendation to GSA and PWD Monterey for PEV acquisition and/or possible follow up research.

II. LITERATURE REVIEW

A. INTRODUCTION

A plethora of articles, journals and blogs praises the benefits of green vehicles and promotes their use. These articles tend to focus on environmental impacts, and do not concentrate on the costs associated with implementation. This is a predictable step for publications, due to the political environment discussed previously, in which the focus on reduction of fossil fuel consumption and greenhouse gas emissions dominates both policy and rhetoric.

Several organizations, however, have published materials concerning green vehicle technologies and their suitability, function, and availability for replacement of traditional vehicle fleets. This research has grown from several strategic documents that outline the importance of—on a National and DON-wide level—reducing our reliance on fossil fuels. The research base for this MBA project stems from an accumulation of data collected from PWD Monterey, industry cost data, government agency resources—such as Department of Energy or DON—and third-party research reports—such as the Advanced Vehicle Testing Activity (AVTA) and Idaho National Energy Laboratory (INEL). Together, these resources provided the foundation for our model, focused our data collection, and assisted in providing our results and recommendations.

B. STRATEGIC GUIDANCE

President Obama prioritized reduced reliance on fossil fuels and increased economic performance of fleet vehicles throughout the U.S. government. His *Presidential Memorandum–Fleet Vehicle Performance* details the way ahead through the federal government, to include mandatory fuel types, "right-sizing," and fleet management (Obama, 2011). This memorandum echoes the 2009 Executive Order 13514, which was then translated by the DON into *Naval Energy—A Strategic Approach. Naval Energy* delineates responsibilities within the department and promotes broad guidelines for fleet and shore energy responsibility. Non-tactical vehicle fleets fall under the "Shore Energy" guidance of this document (Mabus, 2009).

C. ADVANCED VEHICLE TESTING ACTIVITY

The Department of Energy has been collecting data online through the Federal Automotive Statistical Tool (FAST) since 2001, demonstrating the importance of fleet characteristics and dynamics. In recent years, third-party research organizations have conducted in-depth analysis into the feasibility of replacing ICEs with green technologies on the federal fleet level. The current leader in this research is the AVTA, a subcomponent of the Idaho National Laboratory (INL). AVTA-INL has released several major studies as contributions to the field, including two in 2015.

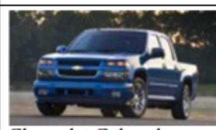
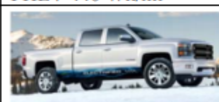
1. Federal Fleet Suitability

The *AVTA Federal Fleet PEV Readiness Data Logging and Characterization Study* provides a look into the composition, usage, and trip distances within a typical federal fleet (Schey & Francfort, 2015c). The study relies on vehicle data logging from fifteen federal agencies; providing a basis for overall fleet vehicle usage. The data collection process, in which 153 vehicles logged over 227,000 miles, found suitable replacements for 97% of the vehicles tested. Scaling this ratio to the fleets of all 15 of the examined federal agencies, Schey and Francfort estimated reductions of 4,843,000 lbs. of CO_2 emissions, and that $1.229M in fuel cost could be saved by transitioning to green vehicles, specifically PHEVs and BEVs (Schey & Francfort, 2015c). While $1.229M in fuel costs initially sounds small, this is over only 1,454 vehicles, leading to an estimate of $845 in fuel savings per vehicle, annually, which is significant.

Data Logging and Characterization provides an excellent method of determination for suitable replacement vehicles. By breaking down monitored vehicles into vehicle types (i.e., compact sedans or pickup trucks) and by mission area (i.e., pool, support, enforcement or transport), a cross-tabled analysis shows which vehicles within each particular mission area are replaceable by determining the average and maximum outing for each mission area (Schey & Francfort, 2015). These baseline vehicle types and mission areas serve as an excellent basis to begin exploring a new agency’s fleet composition, such as the fleet of PWD Monterey.

In addition, the AVTA report explores available replacements, both within GSA’s architecture and available in the market. Schey and Francfort’s recommended PEV replacements based on vehicle types are shown in Figure 6. The recommended vehicles appear to fit the necessary mission related requirements, and, when coupled with cost data, can provide a monetized benefit of replacement at the fleet level.

Figure 6. AVTA Vehicle Replacement Recommendations

Vehicle Class	Current Vehicle Example	Replacement PHEV	Replacement BEV
Sedan – Compact/Subcompact	 Dodge Avenger	 Chevrolet Volt 350 Wh/mi	 Ford Focus Electric 310 Wh/mi
Sedan – Midsize/Large	 Chevrolet Impala	 Ford Fusion Energi* 370 Wh/mi	 Nissan Leaf 300 Wh/mi
SUV and Minivan	 Chevrolet Tahoe	 Mitsubishi Outlander PHEV 440 Wh/mi	 Kia Soul Electic 320 Wh/mi
Pickup Truck	 Chevrolet Colorado	 Via Motors VTRUX 475 Wh/mi	 Nissan eNV200 400 Wh/mi
Pickup Truck (alternate)	 Ford F-150	 Mitsubishi Outlander PHEV 440 Wh/mi	 Kia Soul Electric 320 Wh/mi
Cargo Van	 Chevrolet Express Van	 Via VTRUX Van 475 Wh/mi	 Nissan eNV200 400 Wh/mi
Passenger Van	 Ford E-350	 Via VTRUX Van 475 Wh/mi	 Nissan eNV200 400 Wh/mi

*Note CD range for Fusion Energi is approximately 20 miles.

Generic vehicle replacement PHEV and BEV option for federal fleet vehicle types as recommended by the AVTA. Source: Schey, S., & Francfort, J. (2015c). AVTA Federal fleet PEV readiness data logging and characterization study: Final report. Idaho Falls, ID: Idaho National Laboratory.

2. Installation Fleet Analysis

The AVTA has conducted or is currently conducting multiple studies of similar content to the Federal Fleet analysis discussed above. Specifically, they have created a process for developing implementation recommendations for electric vehicles at military installations, which they have then executed at four establishments within the Department of Defense: Joint Base Lewis McChord, Camp Lejeune, NAS Jacksonville and NS Mayport, and NAS Whidbey Island. These in-depth analyses involve the implementation of a 4-step process to assess the current fleet, sample, analyze and make recommendations. They have broken down the process into four tasks:

- Task 1: Conduct a non-tactical vehicle fleet assessment
- Task 2: Select vehicles for mission and fleet characterizations
- Task 3: Perform a detailed assessment of the selected vehicles and charging infrastructure needs
- Task 4: Prepare adoption approach for PEVs and charging infrastructure (Schey & Francfort, 2015b).

The first report was NAS Jacksonville / NS Mayport, in June 2013; however only Task 1 was published. Joint Base Lewis McChord was assessed from June 2013 to December 2014, with Tasks 1–4 completed and published. Camp Lejeune and NAS Whidbey Island are both in progress, with Tasks 1 and 2 and Tasks 1 through 3, respectively, completed this year.

a. NAS Whidbey Island

Due to its near completion, recent timeframe and similarity to PWD Monterey, we further explore the process and results of the NAS Whidbey Island Assessment. Task 1 was completed in January 2015, and it highlighted the fleet composition, providing graphical representations and key statistics for vehicle type, usage, fuel type, age and usage (Schey & Francfort, 2015b). Task 2 identifies the 60 vehicles used for data collection and eventual assessment (Schey & Francfort, 2015d). Task 3—the fleet analysis portion versus the charging infrastructure analysis—mirrors the process used in the Federal Fleet Sustainability assessment. Using the data collected in Task 2, Schey and

Francfort developed average and maximum usage expectations for vehicle types within each mission area.

A unique addition to the discussion of Whidbey Island is the presentation of commercially available charging stations, or Electric Vehicle Supply Equipment (EVSE) units (Schey & Francfort, 2015e). The implication of available charging infrastructure is that users are provided with an alternative to single location charging, or single charge trips. Depending on the stop time during trips and density of EVSE units, having "out-in-town" infrastructure can significantly increase the single trip or daily trip range of BEVs.

The second part of the NAS Whidbey Island Assessment Task 3 takes an in-depth look at on-base charging infrastructure implementation. Combining the trip data from Task 2 and researching the individual vehicle's parking locations, Schey and Francfort were able to recommend locations where overnight or during work hours charging could take place, and which type of EVSE should be procured (Schey & Francfort, 2015a).

b. Joint Base Lewis McChord

The only base for which the AVTA has completed Task 4 is Joint Base Lewis McChord (JBLM). This large, consolidated Air Force and Army base has a vehicle fleet of just over 1,500 vehicles, and the INEL analysis was completed in 2014 (Schey & Francfort, 2014). Schey and Francfort's Task 4 provides, on a per line-item basis, a recommended replacement vehicle and schedule for the base fleet. Unfortunately, a vast majority of the recommended replacement vehicles are only commercially available (OEM) and not currently approved or supplied through GSA (Schey & Francfort, 2014). This is a challenge we must consider when analyzing the PWD Monterey implementation, given that PWD Monterey operates only GSA leased vehicles.

Implementation Approach for Plug-In Electric Vehicles at Joint Base Lewis McChord: Task 4 provides a per-vehicle estimate of savings in both fuel cost and GHG

emissions. Figure 7 is an example, where the report has selected a specific vehicle, identified its replacement, and detailed the savings.[1]

Figure 7. Task 4 Style Vehicle Replacement

Vehicle G41-1288A

	Make/Model/Year	Ford/Sport Trac /2004
	EPA Class Size	Standard Pickup Truck
	Mission	Pool
	Contact	J. Lamantia/Motor Transport
	Parking Location	Building 100/Col. Joe Jackson Blvd
	Fleet Vehicle ID	G41-1288A
	Fuel Type	Gas/Eth
	Potential Replacement PEV Make/Model	Toyota Rav4 EV
	Potential Annual Fuel Cost Savings	$163
	Potential Annual GHG Reduction	807 lb-CO_2e
	EVSE Type for Recharging	AC Level 2
	Estimated Replacement Year	2015
	Vehicle Age at Estimated Replacement	11
	Odometer at Estimated Replacement Date	15,923

Source: Schey, S., & Francfort, J. (2014). Implementation approach for Plug-in Electric Vehicles at Joint Base Lewis McChord: Task 4. Idaho Falls, ID: Idaho National Laboratory.

The Advanced Vehicle Testing Activity was commissioned by the Department of Defense to generate and provide these reports in preparation for the eventual transition by each base to a green fleet. Not only are they useful to their target audience—the fleet managers at each installation's public works—but also they serve as an excellent reference for factors involved in any base's transition to green vehicle technology. In our case, we use some elements of this four-task process when estimating costs of transitioning the fleet of PWD Monterey.

D. GOVERNMENT ENERGY PUBLICATIONS

Many federal agencies have a hand in reducing government fossil fuel consumption. As mentioned previously, there is strategic guidance provided at a high level to provide a timeline for goals and objectives. In addition, several agencies have

[1] Figure 7 shows a relatively low number of miles on the vehicle to be replaced at the 11 year replacement mark. Due to GSA's leasing policy, the vehicles are scheduled for replacement at 7 years or 60,000 miles, whichever occurs first.

gathered information and developed tools and systems to better promote energy consciousness and green operations. The leader in this is the Department of Energy and its sub-organization the Energy Information Administration, but other agencies including the Department of the Navy and the Department of Transportation have also published relevant materials.

1. Department of Energy

The United States Department of Energy leads in the field of Green Vehicle Technology. It has compiled a vast amount of information into its Alternative Fuels Data Center (AFDC), an online resource for fleet managers. Described as "a comprehensive clearinghouse of information about advanced transportation technologies," this resource has been collecting data on alternative fuels and their advantages and disadvantages since 1991 (Alternative Fuels Data Center (AFDC), 2014). Their collection of tools for the fleet manager includes accurate, easy to use calculators and databases for numerous technologies, vehicle types, and fleet installations. In the case of PWD Monterey, the AFDC's Vehicle Cost Calculator, Petroleum Reduction Planning Tool, AFLEET Tool and GREET Fleet Footprint Calculator all provide ready resources for cost estimation and economic analysis.

The Energy Information Administration (EIA) provides some additional information, although not in the same ready-to-use fashion as the AFDC. EIA's information highlights statistics and major trends on the global and national energy scene, and provides decades of historical information relating to the energy market, sources and consumption.

2. Department of the Navy

In addition to the fleet wide guidance previously discussed, the Department of the Navy has produced guidance to commanders afloat and ashore for how best to use energy resources. According to the Navy's Energy, Environment and Climate Change Homepage:

> The Navy is committed to improving energy security and environmental stewardship by reducing reliance on fossil fuels. The Navy is actively

> developing and participating in energy, environmental and climate change initiatives that will increase use of alternative energy and help conserve the world's resources for future generations. (Office of the Secretary of the Navy, 2015)

The trend in DON energy is to publish strategic or management guidance, while in depth research and analysis is commissioned in studies such as were conducted by the AVTA. Some examples of these fleet level products include:

- *Department of the Navy's Energy Program for Security and Independence*–published in 2010, this "Strategic Energy Roadmap" details Science and Technology, Management and Behavioral developments in support of fossil fuel reduction and the security and independence that comes from it. A theme that echoes the 2009 strategic guidance is the reduction of Non-tactical fossil fuel use by 50% by 2015. (Deputy Assistant Secretary of the Navy (DASN) Energy Office, 2010)

- *A Navy Energy Vision for the 21st Century*–Also published in 2010, the Energy Vision provides a similarly broad scope of plans for the fleet, reiterates the goal of a 50% reduction in non-tactical petroleum use, and details leadership, technology, policy, partnerships and culture as the keys to achieving the Navy's long term energy goals. (Office of the Chief of Naval Operations, 2010)

- *Department of the Navy Strategy for Renewable Energy*–This document was the first produced by the 1 Gigawatt Task Force (1GW TF), and it speaks specifically to Renewable energy production, goals and projects but does not address non-tactical vehicle conversion. (Deputy Assistant Secretary of the Navy (DASN) Energy Office, 2012)

The Navy has been clear in its strategic guidance. With the completion of third-party research and feasibility reports, and clear direction from the organization, the next phase needs to be specific implementation projects in order to obtain the desired 50% reduction in NTV fossil fuel consumption. As we continue, we will outline the cost of implementing a green fleet at PWD Monterey, and explore the petroleum and carbon footprint savings achieved.

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III. BACKGROUND

Though saving energy became a government and military priority in 2009, the United States Navy began its drive specifically toward a green non-tactical vehicle fleet in 2010 when Chief of Naval Operations, Admiral Gary Roughead, released *A Navy Energy Vision for the 21st Century*. Specific to the non-tactical vehicle fleet, the vision states that "by 2015, the Navy will cut in half the amount of petroleum used in its commercial vehicle fleet through phased adoption of hybrid, electric, and flex fuel vehicles" (Roughead, 2010, p. 7). There are currently 46,485 non-tactical, light, medium, and heavy duty vehicles in the Navy's fleet, and as of late 2015, approximately half of the light and medium duty vehicles are alternatively fueled (Energy: Non-Tactical Vehicles, 2015). One of the accomplishments of the Navy's Green Energy Program since 2010 is the replacement of over 900 gasoline vehicles with Neighborhood Electric vehicles (NEVs), with initiatives in place to replace an additional 500 gasoline vehicles with hybrid electric vehicles in the near future. Domestic fossil fuel production, transportation-sector consumption, and the social cost of carbon emissions on the American public are the main driving factors in the transition to Green Vehicle Technologies (GVT).

A. HISTORY OF GREEN VEHICLE TECHNOLOGIES

The first hybrid-electric vehicle (HEV) was created by Ferdinand Porsche in 1898 and featured an ICE that powered two electric motors, which in turn powered the front two wheels (A brief history of hybrid cars, 2013). While Porsche's prototype was initially popular, the release of the mass-produced and much cheaper Ford ICE automobile in 1904 placed the hybrid idea on the backburner. The automotive industry focused on the development of a mass-produced HEV due to the dramatic increase in gasoline prices in the 1970s. In 1997, Toyota released the popular Prius in Japan, followed by Honda's release of the first hybrid vehicle in the United States, the Insight (A brief history of hybrid cars, 2013).

The first BEV was created by William Morrison in Des Moines, Iowa in 1890 and was a six-passenger vehicle that could travel up to 14 miles per hour (MPH) (Matulka,

2014). New York City soon used an electric-powered fleet of 60 taxis and electric vehicles, accounting for a third of the total vehicles used in the country at the time. The popularity of the electric vehicle increased in the 1910s due to increasingly easier access to electricity and the ICE vehicle disadvantages of difficult shifting, unpleasant exhaust, and long start-up times (Matulka, 2014). Inventor Thomas Edison, around this time, worked to develop a battery with increased efficiency for use in electric vehicles. Similar to the decline in popularity of Porsche's hybrid vehicle, the roll-out of the mass-produced and much less expensive Ford, the expansion of the American highway system and lack of electricity outside major U.S. cities cut off the popularity of the electric vehicle (Matulka, 2014). The 1990 Clean Air Act and the 1992 Energy Policy Act renewed American efforts to create a viable electric vehicle. The first mass-produced electric vehicle sold in the United States was General Motors' EV1, which sold from 1996 to 1999 but whose production was ceased due to production costs. When Tesla introduced its development of the mass-produced, luxury electric Model S in 2006 and its release to the public in 2012, the BEV resumed its position in the automotive industry.

The Fuel Cell Electric Vehicle (FCEV) is the third and newest of the major Green Vehicle Technologies, introduced to the American public in 2014 with the Hyundai Tucson and the Toyota Mirai. The FCEV technology uses oxygen from the environment and compressed hydrogen in a fuel cell that creates the electricity that either drives the electric motor or charges the vehicle's battery for future use (Fuel cell vehicles, 2015).

The U.S. Navy has begun replacing its non-tactical vehicle fleet with green alternatives since 2010, as 900 of 46,000-plus fleet vehicles (roughly 2%) are now alternatively fueled. The subject of our analysis, PWD Monterey, is a subsection of Navy Region Southwest and utilizes 92 non-tactical vehicles to include large and midsize sedans, minivans, small two wheel drive pickup trucks, standard-size two and four wheel drive pickup trucks, sport utility vehicles (SUVs), and cargo-type vans. Of these 92 vehicles, 7 large sedans are HEVs (7.6% of the fleet) and there are plans to add electric charging stations and transition more ICE vehicles in the PWD Monterey Fleet to electric vehicles.

B. ENERGY RELIANCE

The transportation sector in the United States currently accounts for 27.12% of the country's overall energy consumption, utilizing 13.45 million bbl/day of petroleum (U.S. Energy Flow, 2014, 2015). By comparison in 2014, the United States produced only 8.65 million bbl/day of crude oil and relied upon foreign imports for another 7.34 million bbl/day (U.S. Petroleum Flow, 2014, 2015). Tremendous advances must be made in the Green Vehicle sector, both in technology and infrastructure to reduce American reliance on foreign imports to sustain the petroleum-thirsty transportation sector.

In addition to the reliance of the American transportation sector on foreign petroleum imports, a second major consideration is the social cost of carbon on the American public. According to the United States Environmental Protection Agency, the social cost of carbon is "an estimate of the economic damages associated with a small increase in CO_2 emissions, conventionally one metric ton, in a given year" or "the value of damages avoided for a small emission reduction" (The social cost of carbon, 2015). The social cost of carbon calculated by the EPA is based on four distinct discount rates: 5%, 3%, 2.5%, and the 95th percentile from the first three rates at a 3% discount rate. According to the Interagency Working Group on Social Cost of Carbon, "[t]he fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution" (Social cost of carbon for regulatory impact analysis-under executive order 12866, 2010, p. 1). The EPA places the 2015 figures of the social cost of carbon at $12 per metric ton (5% discount), $40 per metric ton (3% discount), $62 per metric ton (2.5% discount), and $120 per metric ton (3% 95th percentile) (The social cost of carbon, 2015). An EPA report estimated that a typical vehicle in the United States that attains a fuel efficiency of 21.6 miles per gallon (MPG), creates 8,887 grams of carbon dioxide per gallon burned, and travels 11,400 miles per year, will create 4.7 metric tons of carbon dioxide emissions per year (Greenhouse gas emissions from a typical passenger vehicle , 2014). Given this range of

SC-O2 values, and given that there are 46,485 non-tactical vehicles in the Navy's fleet, the annual Navy non-tactical vehicle SCC is $2.6M to $26.2M.

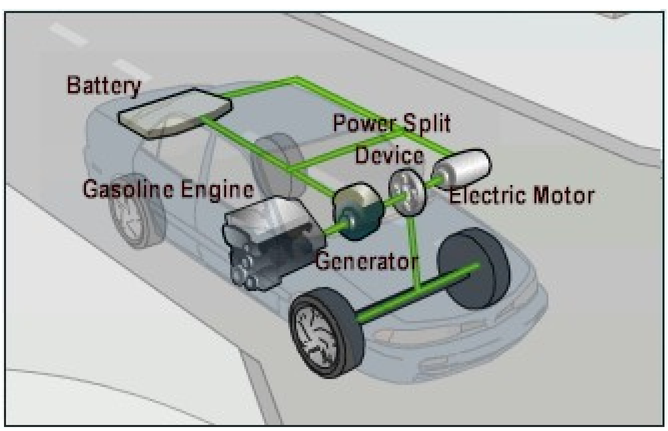
C. MATURE TECHNOLOGIES

This section briefly reviews the highlights of each of the mature and near-future green vehicle technologies and discusses the benefits and drawbacks of each type in contrast with ICE vehicles and with other Green Vehicle Technologies.

1. Hybrid Electric Vehicle

The HEV, shown in Figure 8, uses a combination of an ICE and an electric motor to propel the vehicle, saving the use of the electric motor for propelling the vehicle at efficient speeds and for maintaining auxiliary loads like the radio or air conditioner (How hybrids work, 2015). The ICE is brought online only to propel the vehicle during inefficient driving loads (rapid acceleration) and turns off when the vehicle is stopped or being propelled by the electric motor. The large reduction in ICE usage results in much higher fuel efficiencies when the HEV is compared to ICE counterparts. The HEV uses batteries to store electric energy that assists in acceleration of the vehicle. The batteries are charged through regenerative braking and directly from the ICE.

Figure 8. Hybrid Electric Vehicle



Source: How hybrids work. (2015, November 3). Retrieved from U.S. Department of Energy: fueleconomy.gov Website: https://www.fueleconomy.gov/feg/hybridtech.shtml

HEVs have several advantages that make them more appealing to a consumer when compared to other vehicle types. First and most important is the fuel economy that HEVs achieve. Small and midsize sedan-type HEVs often achieve a fuel economy of 40 to 50 miles per gallon (MPG). When compared to the national average fuel economy of new cars sold in the United States of 25.4 MPG, HEV owners will go almost twice as far as the average consumer on a gallon of gas (Gareffa, 2015). Most ICE vehicles are more efficient travelling at standard highway speeds but most drivers spend a majority of their time driving in city-type driving conditions. An HEV is more efficient in the city because of the smooth acceleration, the ability to take advantage of the electric motor at lower speeds, and increased braking that creates even more electricity for future use. A second advantage to the user, although not to the society, is the availability of federal government tax incentives for green vehicle purchases. Although HEVs are generally more expensive at the outset than their standard ICE counterparts, tax incentives amounting to several thousand dollars ($2,500–$7,500) are available to those who purchase a Hybrid vehicle in addition to the gasoline savings the consumer will see after a few years of much more efficient driving. Finally, HEVs use the onboard ICE more infrequently than a standard ICE vehicle, making vehicle maintenance less frequent and less expensive. The electric motor and battery in the HEV's power plant do not have many moving parts, and require very few maintenance costs, further increasing the lifespan of the vehicle and reducing overall life cycle costs for the consumer.

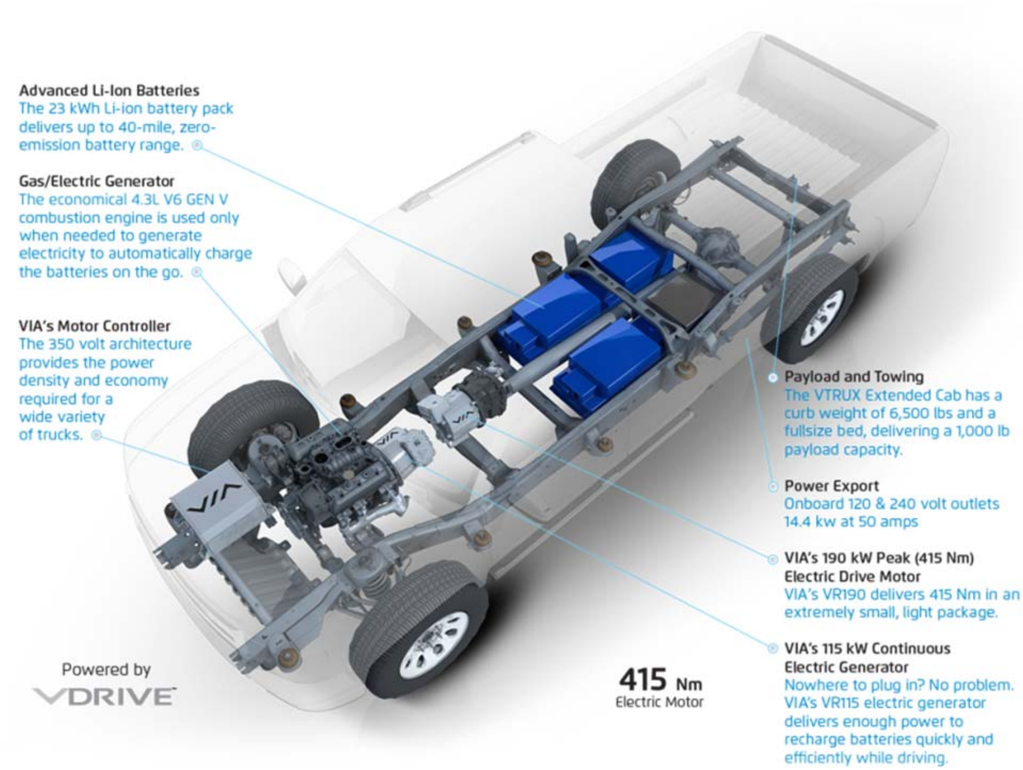
The HEV also has some disadvantages that concern consumers as well. The primary drawback is the increased initial price of the hybrid vehicle. Many consumers will view the idea of paying more initially to save on gasoline costs down the road as not worthwhile. Additionally, the recent shale oil boom in the United States has had a dramatic impact on gasoline prices. As the gasoline prices in the United States decrease, HEV demand and sales also decrease (Glinton, 2014). Likewise, as gas prices increase, demand for HEVs increases and the sales prices increase (Silke Carty, 2012). The second drawback is that the HEV battery has an 8- to 12-year lifespan, after which it must be replaced by the consumer. Larger or higher-performance type HEVs have larger batteries that are more expensive to replace. A new Toyota Hybrid Battery pack costs in the range

of \$3,300 to \$4,000 and a reconditioned battery pack can cost \$800 or more (Bradley, 2014). While the reconditioned battery pack seems like the obvious price option, the number of additional miles that can be driven on a reconditioned battery is lower than the number for a new battery pack. While the HEV offers less-frequent maintenance (The Real Costs of Owning a Hybrid, 2013), the large one-time cost of replacing the battery pack can more than negate the cost savings from other types of maintenance.

2. Plug-In Hybrid Electric Vehicle

The PHEV is similar to the HEV in that it operates on a combination of an electric motor, an ICE and a battery pack (Plug-in hybrids, 2015). However, a PHEV has the ability to plug in and recharge the battery pack using a power source while the vehicle is parked. There are two main types of PHEVs: Series plug-in Hybrids, which are also referred to as Extended Range Electric Vehicles (EREV), and Parallel or blended plug-in hybrids. The EREV, shown in Figure 9, uses the electric motor as the sole source of energy for propulsion and the ICE is used only to generate electricity to recharge the battery when levels are low. For short trips, an EREV will utilize only the electric motor.

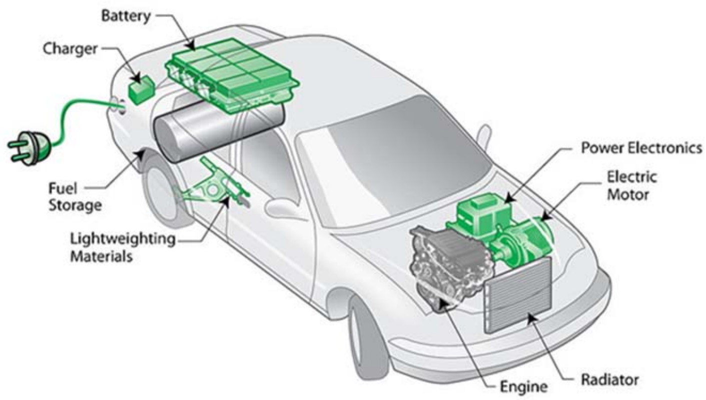
Figure 9. Extended Range Electric Vehicle



Source: Inside the extended-range electric truck. (2015, November 3). Retrieved from Via Motors Website: http://www.viamotors.com/powertrain/

A Blended Plug-In Hybrid, shown in Figure 10, is very similar to an HEV in operation because both the electric motor and ICE are connected to the wheels and provide propulsion. At low speeds or efficient driving conditions, the electric motor turns the wheels. When the vehicle is travelling at higher speeds or in less efficient driving conditions, the ICE is used to turn the wheels. The batteries used in PHEVs can be much larger than those used in HEVs due to the increased range and decreased reliance upon the ICE as compared with an HEV.

Figure 10. Blended Plug-In Hybrid



Source: All sustainable transportation subsidies shouldn't be created equal. (2010, January 18). Retrieved from Energy Insight Website http://www.energyinsight.info/phev_subsidies.html

The PHEV offers advantages over its counterparts that should be carefully considered by consumers. The primary advantage that a PHEV shares with HEVs is the considerable fuel economy. According to the United States Department of Energy's fueleconomy.gov website, a PHEV uses 30–60% less petroleum than a conventional ICE vehicle (Plug-in hybrids, 2015). The PHEV uses some gasoline yet makes even more efficient use of the gasoline it uses compared to an HEV, because the battery obtains a significant portion of its charge from being plugged in to an external power source in addition to the regenerative braking and electricity generation from an ICE. Similar to the HEV, upon purchase of a PHEV, the consumer may take advantage of the green vehicle tax incentives that will assist in offsetting the higher cost of a PHEV. The EREV has a decisive advantage over a BEV because despite relying on the battery to power the electric motor, it still has an ICE generator to charge the battery when its charge drops below a set point. The addition of an ICE generator to an EREV makes the consumer less concerned with the battery charge level and range of the vehicle and gives more flexibility in where and how to fill-up or recharge. A potential advantage of PHEVs over HEVs is the production of fewer greenhouse gas emissions. The PHEV draws much of its power from the electric grid as it is being charged and can be considered to be more efficient in terms of the amount of gasoline required to perform its functions. The energy

used to charge the vehicle's battery can be far cleaner than using a standard ICE or a HEV, depending on the source of the electricity obtained by the local power company. Assuming that the power company uses a heavy blend of renewable sources of energy such as solar, wind, or hydro, the use of the electric grid may be cleaner when compared to its alternatives.

The PHEV has some drawbacks as well that must be considered prior to purchasing the technology. The largest drawback is the amount of time it takes to recharge the electric battery on most PHEVs. Using a home recharging station and a 110 or 120 volt charger, a typical full charge will take as many as 6–8 hours. A commercial charging station that utilizes a 220 to 240 volt connection can still take 1–4 hours for a full charge and 30 minutes for a "fast charge" up to 80% of the battery's overall capacity (Plug-in hybrids, 2015). Most consumers are accustomed to pulling into a gas station and refilling their vehicles to 100% of the gas tank's capacity within five minutes, so a 30 minute "fast charge" can be a tough sell for them. The limited electric charging station infrastructure in the United States is another drawback of plug-in type vehicles. According to an April 2014 Climate Home web article, there were 9,758 electric charging stations in the United States (Wynn, 2014). When compared to 152,995 gasoline filling stations in the United States per a 2014 National Petroleum News report, the American consumer will see an average of 6.38 electric charging stations for every 100 gasoline filling stations (Service station faqs, 2015). Finally, PHEVs use larger and more powerful Lithium-Ion batteries than HEVs. These batteries are more costly to replace and typically do not last as long as an HEV battery because the PHEV is tougher on its battery and will require replacement after fewer battery charging cycles (Plug in hybrid advantages and disadvantages, 2012).

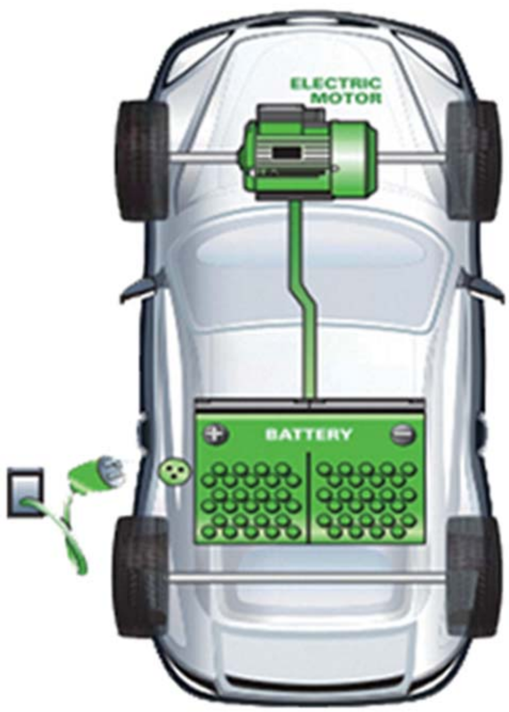
3. Battery Electric Vehicle

The BEV, or "all-electric vehicle" shown in Figure 11, operates solely on an electric powertrain and does not utilize an ICE at all, making it one of the cleanest, mature green vehicle technologies. The battery is charged by a combination of

regenerative braking and plug-in connection from an exterior power source. An electric motor in the BEV provides all of the vehicle propulsion.

The BEV shares many of the same advantages that PHEVs and HEVs provide. Primarily, the BEV has zero tailpipe emissions and only indirectly contributes greenhouse gases to the environment based on the power grid. The BEV is even more efficient than a PHEV because 100% of its propulsion and onboard auxiliary systems are powered through grid generated electricity or regenerative braking.

Figure 11. Battery Electric Vehicle



This typical BEV configuration shows the difference between PEV and PHEV power plants. Source: What's the difference between electric cards and Hybrids? (2015, November 3). Retrieved from Plug'n Drive website: https://www.plugndrive.ca/whats-the-difference-between-electric-cars-and-hybrids

Another advantage is the relatively much lower refueling cost of recharging a BEV as compared with a standard ICE vehicle. The 2015 Nissan Leaf will travel 84 miles on a full 24 kWh battery charge, which equates to 3.5 miles per kWh (Voelcker, 2015).

According to the EIA, the August 2015 national average cost of electricity in the transportation sector was 10.17 cents per kWh, which equates to 2.91 cents per mile travelled in the 2015 Nissan Leaf (Electric power monthly, 2015). The current national averages for ICE efficiency, 25 MPG, and unleaded gasoline price, $2.19 per gallon, mean that a typical ICE vehicle costs 8.76 cents to travel one mile. The average ICE vehicle is therefore three times as expensive to fuel with unleaded gasoline as the 2015 Nissan Leaf is to charge and travel the same distance.

The BEV has similar disadvantages to the PHEV that are further exacerbated by the lack of an ICE. The BEV has a larger, more powerful battery than a PHEV, but the lack of an ICE removes some of the battery capacity security on long trips that PHEVs provide. BEVs provide a small range between charges when compared to ICE vehicle counterparts. Compact vehicles like the 2015 Nissan Leaf can travel 84 miles on a full battery charge while the Tesla Model S luxury sedan can travel 285 miles on a full charge. In comparison, the typical ICE vehicle with a 16 gallon tank and attaining 25 MPG will travel 400 miles between gasoline fill-ups. Other BEV disadvantages previously detailed in the PHEV section include the considerable recharging time for the battery pack, the insufficient American electric charging station infrastructure, and the high cost of replacing the high performance Lithium-Ion Battery.

4. Flex Fuel Vehicles (E85 Capable)

A Flex Fuel capable vehicle is built specifically to be able to handle up to 85% ethanol and 15% regular unleaded gasoline. Concentrations of ethanol in gasoline greater than 15% will destroy a standard ICE vehicle due to the highly corrosive nature of the ethanol. High ethanol concentrations will eat away rubber fuel lines, seals, and gaskets, and will ultimately destroy the engine piston heads in a standard ICE vehicle. Flex Fuel equipped vehicles replace these rubber fuel delivery components with hardened steel and use reconstructed engine components capable of handling fuel with high ethanol concentrations. Combustion of E85 fuel emits fewer carbon byproducts than standard ICEs due to the lower unleaded gasoline concentration. The Flex Fuel equipped vehicle is also capable of operating on 100% unleaded gasoline.

The primary advantage of E85 is that it emits less than half as much Carbon Dioxide as regular unleaded gasoline. According to a University of North Dakota Energy & Environmental Research Center Report, E85 fuel produces 205 grams of Carbon Dioxide per mile compared to 577 grams per mile for regular unleaded gasoline (Timpe & Aulich, 2005).

Ethanol-rich fuel has some strong disadvantages as well. The energy content of E85 is approximately 28% less than that of regular unleaded gasoline, which causes an E85 fueled vehicle to be far less efficient than a vehicle using regular unleaded gasoline (Timpe & Aulich, 2005). If the average ICE vehicle on regular unleaded gasoline gets 25 MPG, the same vehicle on E85 will get approximately 18 MPG. Taking into consideration the national average fuel prices for regular unleaded gasoline and E85 in November 2015, the E85 fueled vehicle costs 11.02 cents per mile travelled and the regular unleaded gasoline fueled vehicle costs 8.78 cents per mile travelled. As a result, when the consumer faces the decision to financially spend more per mile travelled on E85 fuel in order to save carbon dioxide emissions to the environment, it is unlikely that a majority of Americans will choose to use E85. Furthermore, the E85 infrastructure in the United States is very small and largely inaccessible to a majority of the American public. According to U.S. Department of Energy, there are currently 2,674 E85 stations in the United States, mainly concentrated in the Midwest corn-belt region of the United States (AFDC, 2015a). The nearest E85 pump to Monterey County, California is in San Jose, approximately 80 miles away, making the use of the cleaner burning E85 fuel completely impractical for military fleet vehicles based in Monterey County.

5. Congressional Buy American Act

The Buy American Act was developed by Congress and is a requirement for all government purchases greater than $3,000, provided the item’s purchase is consistent with the public interest, and reasonable in cost, and is intended for use within the United States. “Substantially all” of a purchased item is means that at least 50% of the cost of the item’s components must be attributable to American-made components. The Buy American act was intended to ensure American tax dollars are spent on American-made

products. In relation to vehicles required for use by the United States government, purchases are largely limited to the main American automotive manufacturers, Ford, GM, and Chrysler, and several smaller American-owned subsidiary companies.

6. Manufacturer Availability

American vehicle manufacturers Ford and Chevrolet offer a variety of compact to mid-size sedans that utilize Hybrid Electric, Plug-In Hybrid Electric, and Battery Electric options for propulsion. Ford currently offers both the Fusion (mid-size sedan) and C-Max (compact sedan) with either a HEV or PHEV propulsion option, or the Focus (compact sedan) with a BEV propulsion option. Chevrolet offers the Volt (mid-size sedan) with a PHEV propulsion plant and the Spark EV with a BEV propulsion plant. As these technologies and their respective infrastructures are developed, it is probable that more options and more variety in vehicle types that utilize these technologies will become available. At this point, the major American automotive manufacturers do not offer trucks or large vans that utilize HEV, PHEV, or BEV technologies. An American company named Via Motors, however, in Orem, Utah, takes production GM trucks and vans, removes the standard ICE drivetrain and replaces it with a PHEV drivetrain, providing a viable near-term, American made green vehicle technology that can be used to replace a majority of the current non-tactical vehicle fleet.

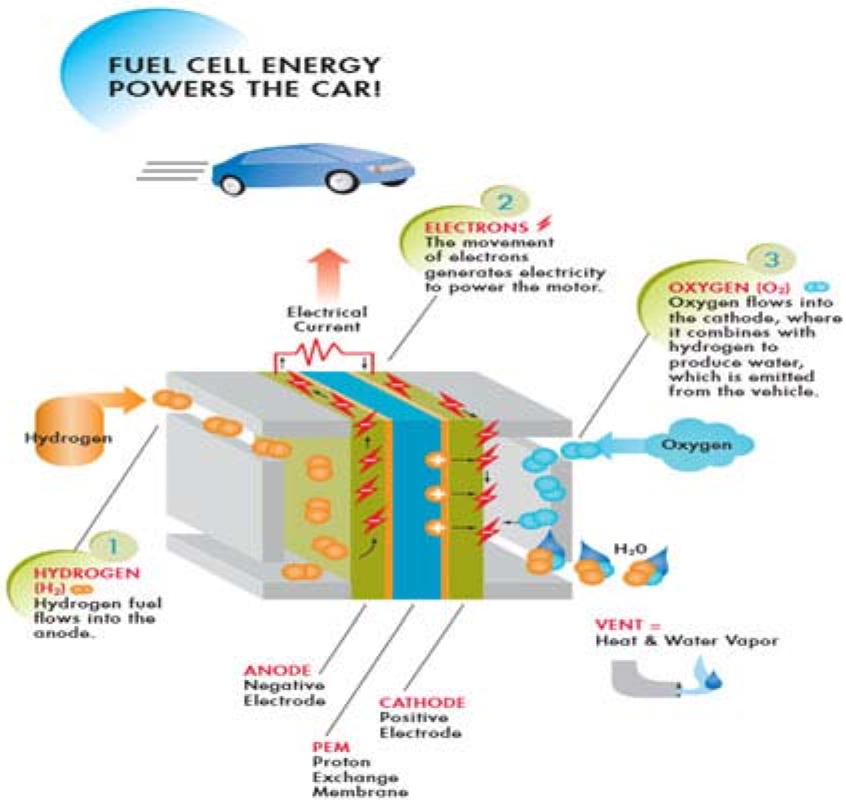
D. FUTURE TECHNOLOGIES

1. Fuel Cell Electric Vehicle

Fuel Cell Electric Vehicles use a chemical reaction, displayed in Figure 12, between oxygen from the outside air and compressed hydrogen from a storage tank equipped on the vehicle to create the electricity required for propulsion with an electric motor and harmless by-products of water and heat. The FCEV further charges its battery with a regenerative braking system. Hydrogen refueling stations are very expensive to build, costing an estimated $1.5 million for a station that can refuel as many as 100 vehicles per week (Hydrogen: How a renewable hydrogen fueling station works, 2015). The FCEV technology is in its infancy in the United States, as there are only 12 refueling stations in the country, focused around a trial, lease-only FCEV program in California

(AFDC, 2015b). Further benefits of the FCEV technology include a 3–5 minute refueling timeframe and a 300 mile range between refueling, making the FCEV very favorable to a consumer when compared to the refueling time and range of a standard ICE vehicle. Similar to the BEV, the operation of the FCEV by itself creates zero greenhouse gases. The process that is used to create the compressed hydrogen stored at refueling stations, however, may create carbon by-products that impact the environment.

Figure 12. FCEV Technology



Source: Hydrogen fuel cell electric vehicles: how fuel cells work. (2014, March 280. Retrieved from California Environmental Protection Agency website: http://www.arb.ca.gov/msprog/zevprog/hydrogen/h2resourxe/fuelcellevs.htm

2. Medium and Heavy Duty Van and Truck PHEV and BEV

While the PHEV and BEV technologies are being developed and the respective infrastructure is expanding in the United States, total transition away from ICE vehicles

cannot take place until the technologies are developed for medium and heavy duty vans and trucks. Producing an electric propulsion technology that can move much heavier vehicles, support four wheel drive transmissions in potentially rough terrains, and support higher payload and towing capacities will take time. Small companies such as Via Motors replace existing ICE heavy duty trucks made by GM with PHEV (EREV) powertrains to support this transition to environmentally friendly trucks and vans. Via Motors was founded in 2010 and began delivering trucks to the American public in 2014, so there are no long term data or substantial reviews available covering the performance or effectiveness of these trucks yet.

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IV. METHODOLOGY

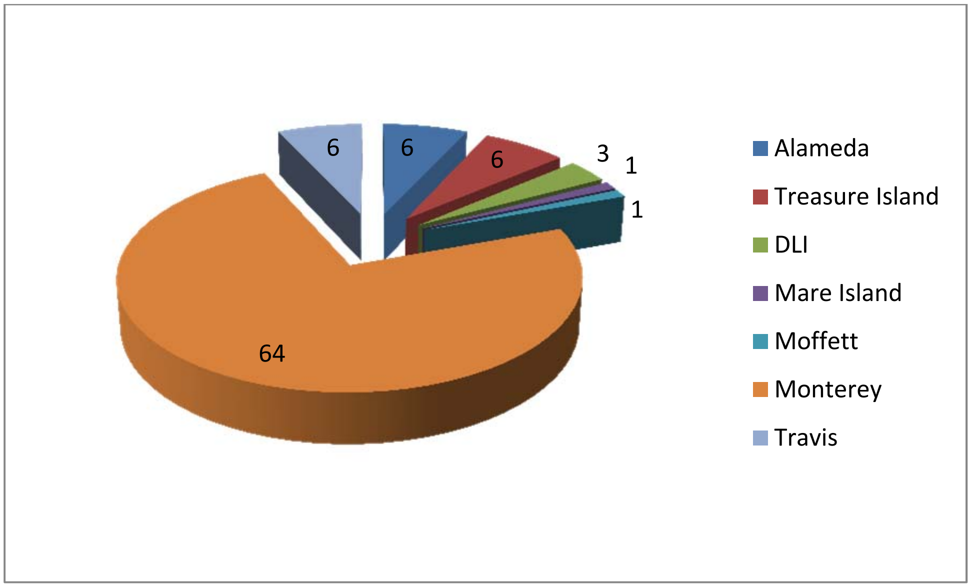
A. PWD MONTEREY CURRENT FLEET DATA

All collected data regarding PWD Monterey's non-tactical vehicle fleet was provided by the NAVFAC fleet transportation manager at NSA Monterey, and assembled for the purpose of this report.

1. Vehicle Location

As stated earlier in this study, the non-tactical light duty vehicle fleet inventory at PWD Monterey consists of 87 vehicles. These vehicles are dispersed throughout seven separate military installations in the Monterey and San Francisco Bay area. The vehicle distribution is shown in Figure 13.

Figure 13. PWD Monterey Vehicle Locations

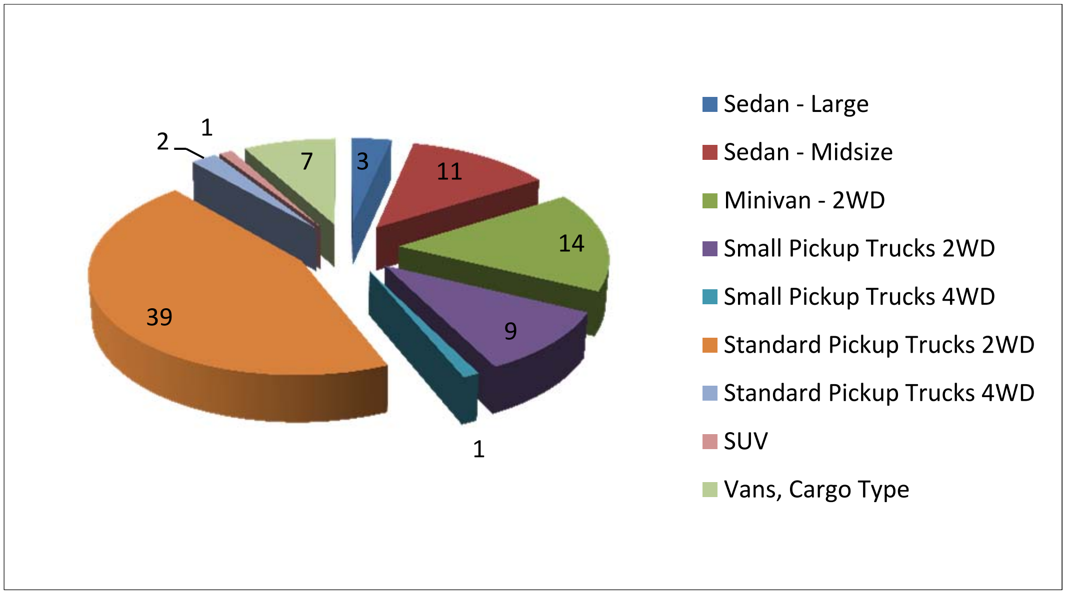


2. EPA Classification

PWD Monterey's non-tactical vehicle fleet includes nine EPA Classifications: Large Cars, Midsize Cars, Minivans, Small Pickup Trucks (2WD), Small Pickup Trucks (4WD), Standard Pickup Trucks (2WD), Standard Pickup Trucks (4WD), SUVs, and

Cargo Vans. The two-wheel drive standard pick-up truck comprises roughly 45% of the entire fleet. The breakdown of the EPA classification is provided in Figure 14.

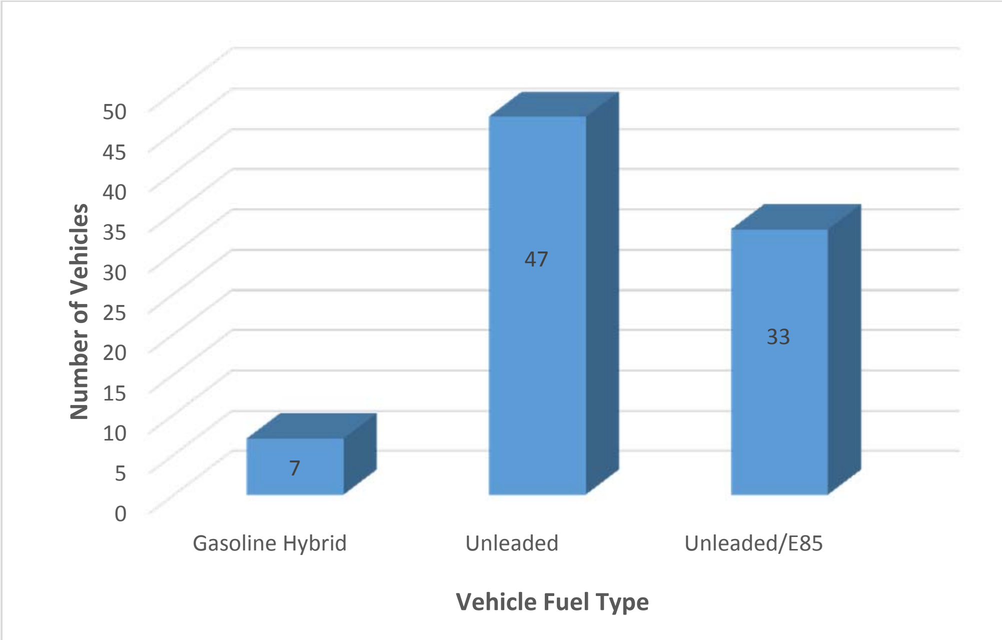
Figure 14. PWD Monterey Fleet EPA Classifications



3. Fuel Type

Currently, 40 of the 87 vehicles in PWD Monterey's non-tactical fleet run on alternative fuel. Seven of the sedans are hybrid vehicles that run more efficiently on gasoline and 33 other vehicles have flex-fuel technology and can operate using E85 fuel, as shown in Figure 15. However, as we mentioned earlier in this study, PWD Monterey isn't able to use the E85 gasoline option for their vehicles because of the lack of available E85 gas stations in the Monterey county area.

Figure 15. PWD Monterey Fleet Fuel Type Breakdown



B. TARGET VEHICLES FOR GREEN TECHNOLOGY

PWD Monterey uses a large variety of vehicles with size and function varying from pure passenger compact sedans to high capacity, one ton pickups. Only some of PWD Monterey's 87 vehicles can realistically be replaced due to GSA and current market availability. We determined which vehicles to replace based upon vehicle type, monthly and daily mileage, and any special usage requirements that might affect replacement.

1. Current Vehicle Type

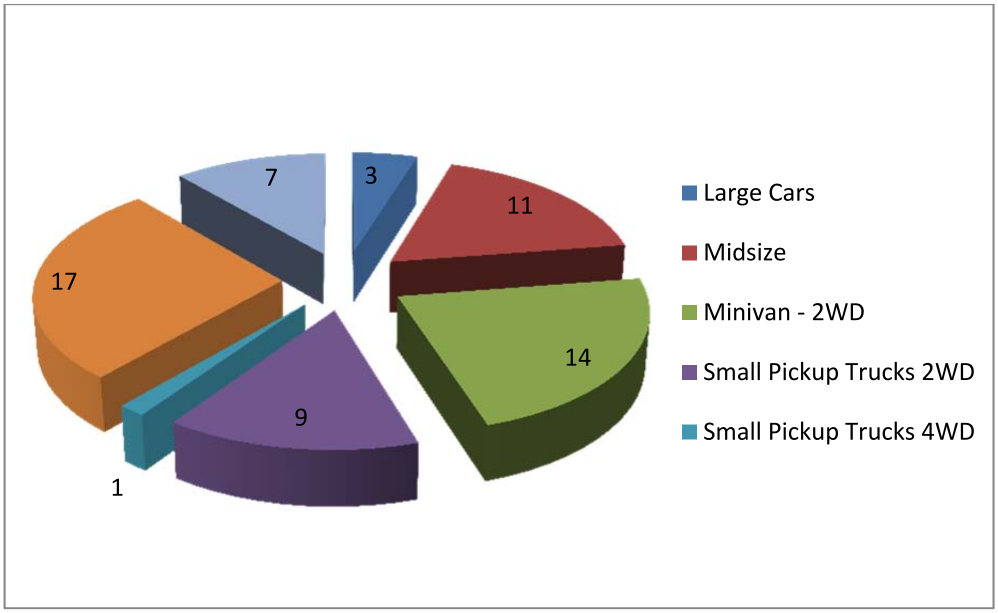
The first step in our methodology was to determine each vehicle's EPA classification, as this would be the most significant replacement suitability indicator. Although some vehicles differ in specific characteristics, the broad-stroke view is sufficient for costing vehicle replacements.

We targeted the following EPA classifications: Large Cars, Midsize Cars, Minivans, Small Pickup Trucks (2WD), Small Pickup Trucks (4WD), Standard Pickup Trucks (2WD), and Cargo Vans. In total, there were 3 vehicles that did not match these

criteria: two Standard Pickup Trucks (4WD) and one SUV (Police Interceptor), bringing our target data set down to 84 vehicles.

Next, we removed heavy duty (HD) trucks because an EREV/BEV replacement for HD trucks is not currently available. Twenty-two of the Standard Pickup Trucks (2WD) are HD – Ford F-250 equivalent or above – and were removed from our target set, bringing the data set to 62 vehicles. The EPA classification breakdown of our targeted 62-vehicle data set is shown in Figure 16.

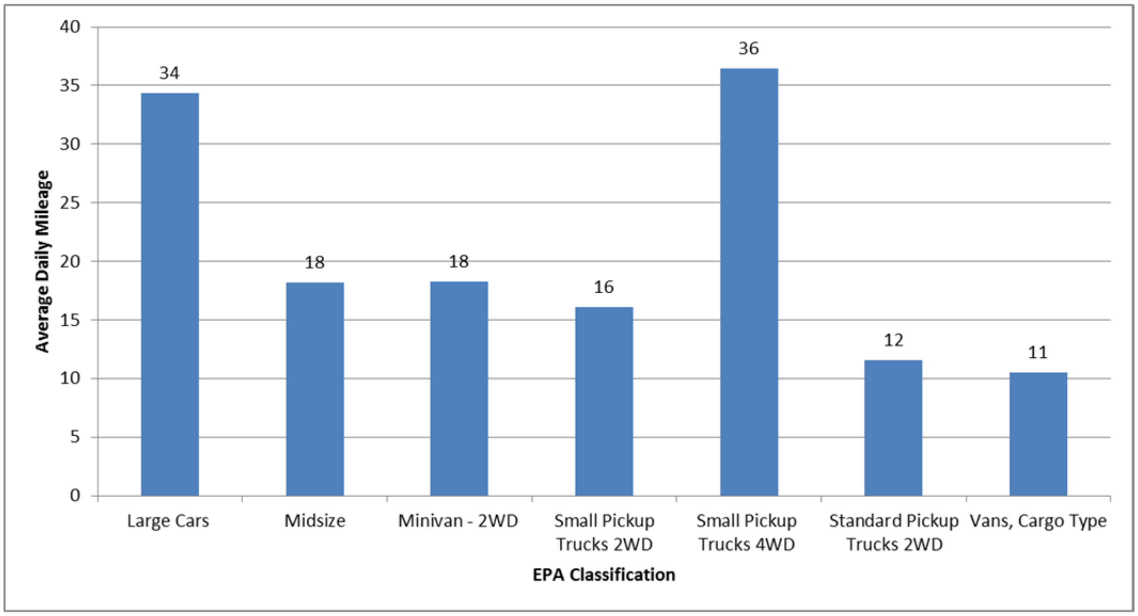
Figure 16. Data Set EPA Classification Breakdown



The next target vehicle factor we considered was the daily mileage due to the all-electric ranges of plug-in type vehicles planned for replacement. The three cutoffs of interest were 19 and 38 miles for cars and 40 miles for trucks and vans based on the performance expectations of their replacement vehicles. When we took the average daily mileage for each EPA classification in our data set, none of the groups of vehicles exceed their respective replacement plug-in all-electric limits, as shown in Figure 17. Analysis of each individual PWD Monterey vehicle by the number of miles actually driven per day found some that exceeded the potential replacement battery-only range limit, but none by

more than five miles per day, which allowed us to continue to use EPA classification averages to conduct our cost analyses.

Figure 17. Average Daily Miles Driven per EPA Classification



For some vehicles in our data set, a direct industry replacement does not exist; however, we chose to consider right-sizing the fleet and estimated the cost of replacing minivans (7 passenger, passenger use) with midsize EREVs, in accordance with shore installation guidance. In all, our data set targets 62 of 87 fleet vehicles in 7 classifications with suitable replacements available.

2. Cost of Target Vehicles

From the data collected, the operating cost to PWD Monterey was calculated for each group. Operating cost consists of two factors: the first is the lease agreement and the second is the SCC.

a. Lease Cost

The leases that PWD Monterey operates with GSA are all inclusive. PWD pays a single rate per vehicle, which includes the vehicle, all maintenance costs, and all fuel costs. Using this calculation allowed us to identify what PWD Monterey pays in total for

each vehicle that they use; however it limited our ability to calculate fuel costs specific to each vehicle, because the costs are consolidated into the flat rate. We therefore used the GSA schedule, which includes a flat rate per vehicle type and a per mile rate, to estimate a rate based on usage, maintenance and fuel. Sample formulae are shown below:

$$\textit{Per Mile Cost} = \textit{Monthly Lease Cost} / \textit{Monthly Miles} \quad (1)$$

$$\textit{Per Mile Cost} = (\textit{GSA Rate} + (\textit{GSA Mile Rate} \times \textit{Monthly Miles})) / \textit{Monthly Miles} \quad (2)$$

The two methods of calculating monthly cost and per mile cost show a significant mismatch. Examples of this rate comparison for the seven EPA classifications are shown in Table 1.

Table 1. Rate Comparison by EPA Classification

Vehicle EPA Classification	Average PWD Lease	GSA Monthly Rate	GSA Per Mile Rate	Total GSA Lease	Difference between PWD Lease and GSA Rate
Large Cars	$971.20	$350.00	$0.22	$513.90	$457.30
Midsize	$413.38	$170.82	$0.12	$217.85	$195.53
Minivan - 2WD	$694.11	$222.57	$0.19	$299.16	$394.95
Small Pickup Trucks 2WD	$347.20	$170.00	$0.23	$251.48	$95.72
Small Pickup Trucks 4WD	$347.20	$209.00	$0.29	$440.78	($93.58)
Standard Pickup Trucks 2WD	$400.38	$172.06	$0.26	$247.51	$152.87
Vans, Cargo Type	$600.46	$220.00	$0.25	$278.80	$321.66

We observed a significant difference between the amounts PWD Monterey is paying for the monthly lease of a vehicle and the GSA scheduled monthly and per-mile rates. The GSA rates, when applied to the monthly mileage of actual vehicles in PWD's fleet, total significantly less than the actual lease amount paid by PWD Monterey. Across the entire data set, PWD Monterey lease agreements include an average 88% premium over the GSA rate given the vehicles' monthly mileage.

b. Social Cost of Carbon

In addition, a SCC analysis was done to provide a $ per mile figure for each of the targeted classifications; however the results demonstrate that SCC on a per vehicle-mile

basis is almost negligible. We followed a multi-step procedure to calculate the SCC for each given vehicle in the data set:

1. To calculate carbon emissions for each vehicle, we took the EPA-provided constant of 8,887 grams of CO_2 burned in a gallon of gasoline (g of CO_2/Gallon) and divided by the combined city and highway fuel economy of each vehicle provided by the U.S. Department of Energy vehicle fuel economy website (www.fueleconomy.gov) (Greenhouse gas emissions from a typical passenger vehicle, 2014). This calculation provided us with grams of CO_2 produced per mile for each vehicle.

2. We took the carbon emissions (g of CO_2/mile) for each vehicle and multiplied it by the number of actual, annual miles driven by the vehicle, giving us the number of grams of CO_2 produced by that vehicle in a year. We then divided by the constant of 1,000,000 grams per metric ton to obtain the number of metric tons of CO_2 produced annually by each vehicle.

3. An EPA-generated fact sheet, *Social Cost of Carbon*, illustrates that four rates should be used when calculating the SCC as explained in Chapter 3: 5%, 3%, 2.5%, and 3% of the 95^{th} Percentile for the first three rates. The *Social Cost of Carbon* fact sheet displays a table with the SCC per metric ton for each of the four discount rates given every five years from 2015 to 2050. We multiplied each vehicle's annual metric tons of CO_2 produced by the four 2015 rates in the EPA table to determine the vehicle's annual SCC. The decision to calculate SCC using four different rates gave us a wide range of social costs. To simplify our process, we looked for the single discount rate that would give the most accurate depiction of social cost. To do this, we referred to the written testimony of economist Robert Murphy before the Senate Committee on Environment and Public Works entitled *The 'Social Cost of Carbon': Some Surprising Facts*, where he states that "Circular A-4 acknowledges that in some cases, the displacement of consumption is more relevant, in which case a real discount rate of 3 percent should be used" (Murphy, 2013). As a result of Murphy's statement, we focused our analysis on a SCC discount rate of 3%.

4. Once the annual SCC was calculated for each vehicle at a 3% discount rate, we divided this annual total by 12 to obtain a monthly SCC, and by the number of annual miles driven to obtain a SCC per mile driven. We then took the average monthly SCC and SCC per mile driven for all vehicles in each of the seven EPA Classifications in our data set to provide the data shown in Table 2.

Table 2. SCC by EPA Classification

Vehicle EPA Classification	Monthly SCC ($/Month)	SCC / Mile ($/Mile)
Large Cars	12.20	0.01616
Midsize	3.99	0.00998
Minivan - 2WD	7.33	0.01824
Small Pickup Trucks 2WD	7.03	0.01987
Small Pickup Trucks 4WD	17.82	0.02222
Standard Pickup Trucks 2WD	5.48	0.02158
Vans, Cargo Type	6.00	0.02585

c. Total Cost

By combining the lease cost and SCC, we determined the total cost to PWD Monterey for each of the types of vehicles they operate. A summary of the data set vehicle class per mile costs is shown in Table 3.

Table 3. Data Set Vehicle Cost Breakdown by EPA Classification

Vehicle EPA Classification	PWD Lease / Mile	GSA Lease / Mile	SCC / Mile	Cost / Mile (PWD)	Cost / Mile (GSA)
Large Cars	$ 1.36	$ 0.89	$ 0.0162	$ 1.38	$ 0.91
Midsize	$ 1.57	$ 1.75	$ 0.0100	$ 1.58	$ 1.76
Minivan - 2WD	$ 2.36	$ 2.11	$ 0.0182	$ 2.38	$ 2.13
Small Pickup Trucks 2WD	$ 1.68	$ 1.77	$ 0.0199	$ 1.70	$ 1.79
Small Pickup Trucks 4WD	$ 0.43	$ 0.55	$ 0.0222	$ 0.45	$ 0.57
Standard Pickup Trucks 2WD	$ 1.77	$ 0.83	$ 0.0216	$ 1.79	$ 0.85
Vans, Cargo Type	$ 3.01	$ 0.88	$ 0.0259	$ 3.04	$ 0.91

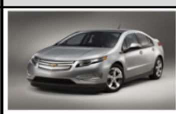
C. PLANNED REPLACEMENT VEHICLES

The most logical green vehicle technology that can be used to replace PWD Monterey's fleet at the current time is the PHEV. The PHEV was chosen over other GVTs due to the fact that PHEVs are readily available on the open market in the vehicle classifications needed by PWD Monterey, the plug-in infrastructure in place along the Central California coast is more than sufficient to support the daily use of a plug-in GVT, and the PHEV will support the daily ranges that PWD Monterey vehicles travel with almost entirely battery-only operation.

1. Description of Suitable Alternatives

This section will detail the specific, market-available PHEVs that serve as optimal replacements for the current PWD Monterey fleet. The battery size, battery charging times, and rated battery-only and combined ranges for each replacement vehicle are detailed in Table 4.

Table 4. Selected Suitable Replacements

Vehicle	Image	EPA Classification	Battery Size (kWh)	120 Volt Charging Time (Hrs)	240 Volt Charging Time (Hrs)	Battery Range (Miles)	Combined Range (Miles)
2015 Chevrolet Volt		Compact Car	17.1	8-10	4	38	380
2015 Ford Fusion Energi		Midsize Car	7.6	7	2.5	19	550
2015 Via VTRUX		Standard Pickup Truck 4WD	23	10	3	40	400
2015 Via VTRUX		Cargo Type Van	23	10	3	40	350

2. Matching Target Replacement Vehicles with Suitable Alternatives

In order to conduct a cost estimate and economic analysis, the selected replacement vehicles were matched to target vehicles in PWD Monterey's fleet based upon the most appropriate EPA class. We considered only American-made vehicles due to the requirements of the "Buy American" Act. Although there are several viable replacement PHEV options made by Nissan, Hyundai, Toyota, and BMW, GSA typically purchases or leases vehicles manufactured by the major U.S. manufacturers.[2] Of the American automotive manufacturers, only Chevrolet, Ford, and Via Motors produce PHEV-type vehicles. Our analysis considered some fleet "right-sizing" for requirements

[2] This raises an interesting issue: when is a car made by an American company "American" and when is a car made in America by a foreign company "American?" Measured by value added in America, some cars made by foreign companies are more American than some cars made by American companies. The authors' casual observation is that "buy American" is taken in practice to mean, in most cases, buy from American companies.

that could be optimally met with a PHEV in a slightly different EPA class than the vehicle being replaced. The current fleet vehicles by EPA classification and the PHEV types that will replace each are displayed in Table 5.

Table 5. PWD Monterey Replacement Vehicles

Number	Vehicle Make	Vehicle Model	Vehicle EPA Classification	Replacement Vehicle	Replacement EPA Classification
2	Hyundai	Sonata Hybrid	Midsize	Chevrolet Volt	Compact Car
5	Ford	Fusion HEV	Midsize	Chevrolet Volt	Compact Car
4	Hyundai	Elantra	Midsize	Chevrolet Volt	Compact Car
3	Chevrolet	Impala	Large Cars	Ford Fusion Energi	Midsize Car
7	Dodge	Caravan	Minivan - 2WD	Ford Fusion Energi	Midsize Car
1	Dodge	Ram C/V	Minivan - 2WD	Ford Fusion Energi	Midsize Car
5	Dodge	Grand Caravan	Minivan - 2WD	Ford Fusion Energi	Midsize Car
1	Chevrolet	Uplander	Minivan - 2WD	Ford Fusion Energi	Midsize Car
3	Ford	E-350	Vans, Cargo Type	VIA Van	Vans, Cargo Type
3	Ford	E-350 Super Duty	Vans, Cargo Type	VIA Van	Vans, Cargo Type
1	Ford	E-150	Vans, Cargo Type	VIA Van	Vans, Cargo Type
5	Ford	Ranger	Small Pickup Trucks 2WD	VIA VTRUX	Standard Pickup Trucks 4WD
1	Dodge	Dakota	Standard Pickup Trucks 2WD	VIA VTRUX	Standard Pickup Trucks 4WD
4	Chevrolet	Colorado	Small Pickup Trucks 2WD	VIA VTRUX	Standard Pickup Trucks 4WD
11	Chevrolet	Silverado 1500 (EC)	Standard Pickup Trucks 2WD	VIA VTRUX	Standard Pickup Trucks 4WD
1	Ford	F-150	Standard Pickup Trucks 2WD	VIA VTRUX	Standard Pickup Trucks 4WD
2	Dodge	Ram 1500	Standard Pickup Trucks 2WD	VIA VTRUX	Standard Pickup Trucks 4WD
2	Chevrolet	Silverado 4X2	Standard Pickup Trucks 2WD	VIA VTRUX	Standard Pickup Trucks 4WD
1	Chevrolet	Colorado 4X4	Small Pickup Trucks 4WD	VIA VTRUX	Standard Pickup Trucks 4WD

3. Special Replacement Considerations

We used some special considerations to decide how to replace some of the vehicles in the current PWD fleet based on suitable PHEVs that are available and the operational requirements that must be met with each vehicle. VIA Motors makes one VTRUX model, available only with 4-Wheel Drive, but all of PWD Monterey’s 2- and 4-Wheel Drive small and standard size pickup trucks were replaced with the VTRUX. Additionally, we determined that the missions that currently use a four door midsize sedan can also be accomplished with a compact sized car. Similarly, the missions that currently use large cars or minivans can also be accomplished with a midsize car.

V. COST ESTIMATION AND ANALYSIS

The cost model for PWD Monterey has two main sections: vehicles and infrastructure. By estimating the costs of the vehicles and comparing them to the current vehicle costs, we have provided an estimate for present year cost savings. Adding infrastructure provides the total cost of the transition. Furthermore, section three contains an analysis of the net present value (NPV) of these savings, providing a seven year stream of the costs incurred and benefits provided.

A. NEW VEHICLE COST ESTIMATE

Overall replacement vehicle cost includes three cost components, estimated in a number of ways. The three cost components included are lease cost, maintenance cost, and electric supply cost. This cost process is broken down in the following sections.

1. Lease Cost

Lease cost was estimated using two methods. The first method is by using the GSA vehicle lease schedule. The schedule provides a monthly cost and a per-mile rate for fuel and maintenance, which is then applied to the average monthly mileage of each EPA classification, and added to the total. We also adjusted this rate with the 88% difference found between current vehicles' lease prices and GSA scheduled rates as discussed in our Methodology chapter.

For example, the GSA scheduled rate for a Chevrolet Volt is listed under GSA equipment code 1210, Compact sedan (electric), as $171.00 monthly with a $0.095/mile mileage rate (U.S. General Services Administration, 2015). Volts are being used to replace midsize vehicles, which average 400.04 miles per month. We could then calculate the GSA scheduled rate as:

Monthly Rate + (Mileage Rate x Average Mileage) = Monthly Lease Cost

Or with, as an example, the numbers provided above:

$171.00 + ($0.095 x 400.04) = $209.00 per month

Using the factor of 88%, which we found that PWD Monterey historically pays over standard GSA rates, the new cost for a Volt would be $392.93 per month. These calculations were repeated for each of the new vehicles in our model, as shown in Table 6.

Table 6. GSA Estimate and Factored Estimate

EPA Classification	Replacement Vehicle	Total Cost (GSA Estimate)	Total Cost (88% Factor)
Large Cars	Fusion Energi	$ 256.62	$ 482.44
Midsize	Volt	$ 209.01	$ 392.93
Minivan - 2WD	Fusion Energi	$ 218.93	$ 411.58
Small Pickup Trucks 2WD	VTRUX	$ 327.26	$ 615.25
Small Pickup Trucks 4WD	VTRUX	$ 459.50	$ 863.86
Standard Pickup Trucks 2WD	VTRUX	$ 343.20	$ 645.21
Vans, Cargo Type	VTRUX Van	$ 330.03	$ 620.45

The second estimate is a market lease cost, which was then combined with a market electricity cost and an observed maintenance cost. Market costs were determined from the respective manufacturer website for each vehicle. Chevrolet lists the average lease cost for the Volt to be $249.00 per month; Ford estimates a Fusion Energi at $299.00 per month, and VIA Motors lists both VTRUX and Vans at $752.00 per month.

The difference between market rates and the GSA rates is that the market rates are non-inclusive of fuel or electricity costs and, in some cases, do not include maintenance costs. VIA's leases are an exception, as they do include maintenance but not fuel or electricity. In order to estimate the maintenance costs of the Chevrolet Volt and Ford Fusion Energi, we referred to historical data collected by the AVTA on their Volt and Fusion Energi test platforms. The tested Volt vehicles traveled a combined 468,567 miles and averaged $0.02 per mile in maintenance costs, and the Fusion Energi vehicles traveled a combined 345,455 miles and averaged $0.0175 per mile in maintenance costs. These, therefore, are the two figures we used as our market vehicle maintenance rate (Advanced Vehicle Testing Activity, 2015).

2. Power from the Grid

Public electric power for PWD Monterey's area of responsibility is supplied by Pacific Gas and Electric (PG&E). We determined from PG&E's electric power schedules that the rate of electricity per kWh is $0.24 for summer months and $0.16 for winter months, combined for a summary average of $0.21 per kWh (Pacific Gas and Electric, 2015). We used the PG&E summary average for the cost per kWh in our model. The electricity rate per mile driven was calculated based on the battery capacity and all-electric range of the replacement vehicles. Electricity costs per mile for the replacement vehicles are shown in Table 7.

Table 7. Vehicle Battery Size and Electric Cost Per Mile

Replacement Vehicle	Battery Size (kWh)	Range	kWh / Mile	Cost / Mile (Market)
Volt	17.1	38	0.45	$0.095
Fusion Energi	7.6	19	0.4	$0.084
VTRUX	23	40	0.575	$0.121
VIA Van	23	35	0.657	$0.140

3. Social Cost of Carbon

The SCC produced by PG&E's electric grid was calculated based on PG&E's 2014 Power Content breakdown, detailed in Appendix 1. The SCC per mile for each of the replacement vehicles is listed in Table 8. Relative to the electricity and lease rates per mile, SCC is negligible and rounded to zero in our total monthly cost model.

Table 8. Replacement Vehicle SCC per Mile

Replacement Vehicle	SCC / Mile
Chevrolet Volt	$ 0.00436
Ford Fusion Energi	$ 0.00388
VIA VTRUX	$ 0.00557
VIA VTRUX VAN	$ 0.00637

We then applied the SCC per mile rate to the monthly miles travelled per EPA classification that these vehicles are replacing, as shown in Table 9.

Table 9. Replacement Vehicle Average Monthly SCC by EPA Classification

EPA Classification	Replacement Vehicle	SCC per Month
Large Cars	Fusion Energi	$ 2.93
Midsize	Volt	$ 1.74
Minivan - 2WD	Fusion Energi	$ 1.56
Small Pickup Trucks 2WD	VTRUX	$ 1.97
Small Pickup Trucks 4WD	VTRUX	$ 4.47
Standard Pickup Trucks 2WD	VTRUX	$ 1.41
Vans, Cargo Type	VTRUX Van	$ 1.48

4. Total Vehicle Costs

The total cost of a replacement vehicle is a combination of lease cost, maintenance cost, and electric supply cost. For each EPA classification, we have selected a replacement vehicle and applied the observed monthly mileages from PWD Monterey's current fleet to calculate total costs and costs per mile. The total costs, estimated through both methods, and the cost per mile are shown in Table 10.

Table 10. Replacement Vehicle Total Monthly and Per Mile Costs

EPA Classification	Replacement Vehicle	Total Cost (GSA-F)	Total Cost (Market)	Cost / Mile (GSA-F)	Cost / Mile (Market)
Large Cars	Fusion Energi	$ 482.44	$ 368.77	$ 1.21	$ 0.93
Midsize	Volt	$ 392.93	$ 292.60	$ 0.71	$ 0.53
Minivan - 2WD	Fusion Energi	$ 411.58	$ 331.88	$ 0.99	$ 0.80
Small Pickup Trucks 2WD	VTRUX	$ 615.25	$ 785.08	$ 1.57	$ 2.01
Small Pickup Trucks 4WD	VTRUX	$ 863.86	$ 849.17	$ 7.58	$ 7.45
Standard Pickup Trucks 2WD	VTRUX	$ 645.21	$ 792.81	$ 2.61	$ 3.21
Vans, Cargo Type	VTRUX Van	$ 620.45	$ 780.10	$ 1.96	$ 2.46

We believe the GSA rate to be a more accurate representation of what PWD Monterey will pay based on comparison to their current fleet and how their lease agreements are currently structured. Using GSA's schedule to estimate vehicles currently in GSA inventory (Volts and Fusion Energis) is accurate. For VIA Motors vehicles, the closest GSA estimate was based on the equipment code "Standard Pickup Trucks, Special Services," because EREV trucks are not in the GSA inventory at this time. As a result, we have selected the market rate, which includes vehicle maintenance, for further cost calculations regarding the VTRUX and Vans.

B. CHARGING INFRASTRUCTURE

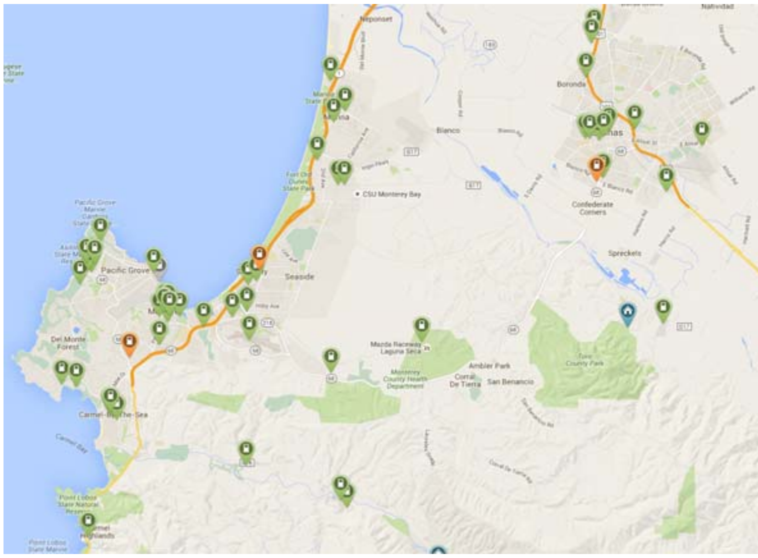
Infrastructure is a large, one-time cost associated with a fleet transition to PHEVs and is required for battery depletion mode usage in the vehicles. In order to fully assess the cost of the transition, an infrastructure cost must be calculated.

1. Charging Environment

The PWD Monterey AOR is heavily populated with publicly-available vehicle charging stations. The San Francisco Bay, Sacramento, Silicon Valley, and Monterey Peninsula areas are home to hundreds of public charging stations, including numerous high-power stations.[3] There are over 60 public charging stations in Monterey Peninsula alone. The electric charging station availability in Monterey, San Francisco, and the Northern Bay and Sacramento are shown in Figures 18 to 20.

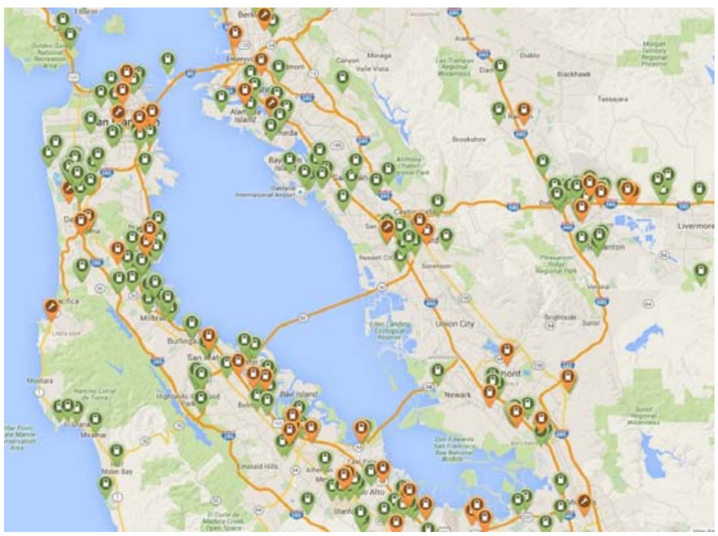
[3] High-power stations refers to Direct Current Fast Charging (DCFC) Stations and Tesla Superchargers, which are above L1 and L2 charging, but require special connections onboard PHEVs.

Figure 18. Monterey Peninsula Public Charging Stations



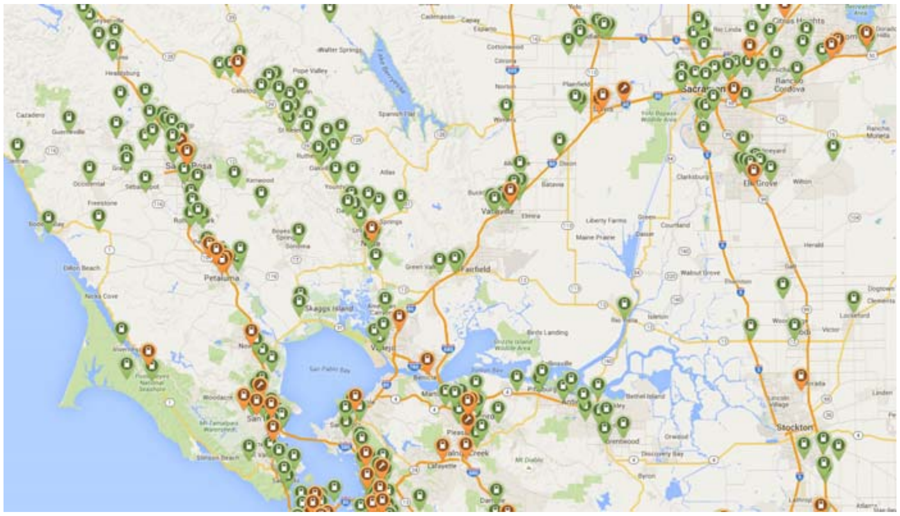
Source: Recargo Inc. (2015). PlugShare.com. Retrieved November 15, 2015 from http://www.plugshare.com

Figure 19. Bay Area (South) Public Charging Stations



Source: Recargo Inc. (2015). PlugShare.com. Retrieved November 15, 2015 from http://www.plugshare.com

Figure 20. Bay Area (North) and Sacramento Public Charging Stations



Source: Recargo Inc. (2015). PlugShare.com. Retrieved November 15, 2015 from http://www.plugshare.com

The wide availability of charging stations in the AOR allows for greater flexibility and extended battery-only ranges for vehicles in PWD Monterey’s AOR.

2. Electric Vehicle Supply Equipment

EVSE can be broken down into 2 categories, 120V and 240V, commonly referred to as Level 1 (EVSE L1) and Level 2 (EVSE L2), respectively. Commercially available PHEVs typically come with an L1 charger on-board, which can be plugged into any standard 120V electrical socket. Level 2 requires a wall box, but can be installed in both commercial and residential settings. The advantage of a L2 unit is the speed at which it charges, but it is significantly more expensive than an L1 and often requires modification to existing circuitry when installed. According to an AVTA assessment of charging station installation, the cost for a single unit of EVSE in differing installations is $979.30 for a single L1, $2393.70 for a single L2 and $2,065.70 each for a bank of multiple L2 units[4] (Morrow, Karner, & Francfort, 2008).

[4] AVTA’s infrastructure report from Morrow et. al. estimates installation costs of $878 for L1, $2,146 for L2 and $2,059 for multi L2 in 2008 dollars. Using the 2015 Joint Inflation Calculator, the numbers reflected here are adjusted for 2015. (Naval Center for Cost Analysis, 2015).

In the PWD Monterey environment, a number of both Level 1 and Level 2 units are required to make effective use of the green vehicle fleet. Because of the nature of PWD's work, these vehicles are available for charging overnight, and we assume they will be plugged in and charged from work-day completion until work-day beginning every day. Because overnight charging is available, EVSEs must be matched to the battery size of the vehicle, in order to ensure a full charge at work-day start. Of the 4 vehicles chosen as replacements, only the Ford Fusion Energi has a battery capacity which can be easily charged overnight via L1 charging. Therefore, we used 17 EVSE L1s and 45 EVSE L2s in our analysis.

Further breaking down the required infrastructure, we assessed the number of L1 and L2 charging stations at each base, and computed the total infrastructure cost at each, shown in Table 11. In addition, in order to find a total cost across each EPA classification, we attributed the cost of individual charging stations to the class of car it would service, and found a cost per EPA classification, as shown in Table 12.

Table 11. Charging Stations and Total Costs at PWD Monterey Facilities

Base	EVSE L1	Single L2	Multi L2	Total Cost
NAS Alameda	1		5	$ 11,307.80
Mare Island Naval Complex		1		$ 2,393.70
NAS Moffett Field	1			$ 979.30
NSA Monterey	11		29	$ 70,677.60
Presidio of Monterey	2	1		$ 4,352.30
Travis Air Force Base	2		4	$ 10,221.40
Treasure Island Naval Complex			5	$ 10,328.50
	17	**2**	**43**	**$ 110,260.60**

Table 12. Cost of EVSE allocated to EPA Classifications

EPA Class	EVSE L1	Single L2	Multi L2	Total Cost
Large Cars	3			$ 2,937.90
Midsize Cars		1	10	$ 23,050.70
Minivans	14			$ 13,710.20
Small Trucks 2WD			9	$ 18,591.30
Small Trucks 4WD			1	$ 2,065.70
Standard Trucks		1	16	$ 35,444.90
Vans			7	$ 14,459.90
	17	**2**	**43**	**$ 110,260.60**

The total infrastructure cost is estimated to be $110,260.

C. COST COMPARISON

By comparing the target vehicle monthly costs (Chapter IV, Table 1) and the replacement vehicle Total costs (Chapter V, Table 10), we were able to determine the benefit (or additional cost) of the replacement vehicle lease on both monthly and annual basis for each EPA Classification. This cost comparison is shown in Table 13.

Table 13. Comparison of Current and Replacement Lease Costs

EPA Classification	Number Replaced	Monthly per Vehicle			Monthly Class Total (Add'l Cost)	Annual Class Total (Add'l Cost)
		Current Cost	Replacement Estimate	Savings (Add'l Cost)		
Large Cars	3	$ 971.20	$ 482.44	$ 488.76	$ 1,466.28	$ 17,595.36
Midsize	11	$ 413.38	$ 392.93	$ 20.45	$ 224.95	$ 2,699.40
Minivan - 2WD	14	$ 694.11	$ 411.58	$ 282.53	$ 3,955.42	$ 47,465.04
Small Pickup Trucks 2WD	9	$ 347.20	$ 785.08	$ (437.88)	$ (3,940.92)	$ (47,291.04)
Small Pickup Trucks 4WD	1	$ 347.20	$ 849.17	$ (501.97)	$ (501.97)	$ (6,023.64)
Standard Pickup Trucks 2WD	17	$ 400.38	$ 792.81	$ (392.43)	$ (6,671.31)	$ (80,055.72)
Vans, Cargo Type	7	$ 600.46	$ 780.10	$ (179.64)	$ (1,257.48)	$ (15,089.76)

Note: Numbers listed in parentheses are negative numbers, indicating the total additional costs of implementing that class of vehicles.

From this calculation, we can see that only Large Cars, Midsize Cars, and Minivans realize a benefit in the snapshot of the single year's cost. Part of this is due to the lower per mile maintenance cost and therefore lower GSA scheduled rate, but a majority of this cost savings is due to right sizing, especially in the case of minivans,

which were replaced with Fusion Energis. The trucks and vans, however, show a significant increase in cost, almost entirely attributable to the substantially higher lease costs for VIA vehicles.

D. NET PRESENT VALUE

In order to determine whether the cost of higher lease payments (inclusive of fuel and maintenance) would be offset by other savings, a net present value (NPV) was calculated for the 7 year expected useful life of each EPA classification. The NPV included the annual cost savings (or additional cost) of the replacement vehicle leases, the one-time infrastructure cost, and the annual SCC savings per vehicle EPA classification, factored to estimate 35 years of cumulative damage. Given the guidance of OMB Circular A-94, we used a 7% market rate when calculating the NPV (Office of Management and Budget, 2015). The sample NPV calculation for the Large Cars EPA Classification is shown in Figure 21, and the remainder of the EPA classifications can be found in Appendix II. A summary of the EPA Classifications' NPVs is shown in Table 14.

Figure 21. Sample Input and Results for NPV Calculation

Input	
Number of Vehicles Replaced:	3.00
One-Time Infrastructure Cost	$ 2,937.90
Annual Lease Benefit	$ 1,466.28
Annual SCC Benefit	$ 642.85
Discount Rate	7%
Time Period (Years)	7.00

Results	
Large Car Lifetime Costs	$ 2,937.90
Large Car Lifetime Benefits	$ 13,475.84
Sum of Net Benefits	$ 10,537.39

Table 14. Summary of EPA Classification NPV over 7 Years

EPA Classification	**Sum of Net Benefits (7 years)**	
Large Cars	$	10,537.39
Midsize Cars	$	(2,071.98)
Minivans	$	301,500.15
Cargo Vans	$	(106,118.92)
Small Pickup Trucks (2WD)	$	(313,717.50)
Small Pickup Trucks (4WD)	$	(38,582.21)
Standard Pickup Trucks (2WD)	$	(534,964.40)
Total	**$**	**(683,417.47)**

Note: Numbers listed in parentheses are negative numbers, indicating the total additional costs of implementing that class of vehicles.

Of note, only the Large Car (replaced with Fusion Energi) and the Minivan (also replaced with Fusion Energi) segments have a net benefit over the 7 year useful life. We attribute this to the benefits of right sizing more than to the benefits of green technology. Our model uses smaller, less expensive vehicles to conduct the same mission as larger, more costly platforms such as Minivans. Midsize vehicles would also be beneficial, but the large cost of implementing Level 2 EVSE – required to charge the large battery found in Chevrolet Volts – outweighs the social and lease cost benefits. Trucks, given their current costs, do not have a realizable net benefit.

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VI. RECOMMENDATIONS

A. STOPLIGHT CHART

Assessing a replacement fleet for PWD Monterey has led to several conclusions about the way forward for green vehicle technology. Comparing the current fleet with the benefits and additional costs of PHEV replacements across seven EPA classifications has provided a monetary basis (but one that includes the value of environmental benefits) for whether action should or should not be taken. Based on our findings, our recommended actions are summarized in Figure 22.

Figure 22. PWD Monterey PHEV Replacement Recommendations

Vehicle Classification	NPV 7 Years	Go/No-Go	Discussion
Midsize Cars	$ (2,071.98)		Midsize cars are slightly negative in the NPV calculation. Because seven midsize vehicles are already HEVs, the benefits were not substantial in comparison. Also, the required number of L2 ESVE makes this a costly option initially and is not fully compensated by the long term SCC savings. Considering the benefits estimated in the Large Car and Minivan segments, we recommend addressing midsize vehicles on a case by case basis, as they are the most mature and easiest to transition in order to meet strategic goals.
Large Cars	$ 10,537.39		Large cars have a positive net benefit and should be transitioned to PHEVs. These vehicles are used frequently (averaging 34 miles daily) and, therefore, will generate the largest benefit of transitioning to a less expensive platform. Additionally, the recommended replacement, Ford Fusion Energi, requires only a L1 EVSE, which has a smaller up-front cost of conversion.
Minivans	$ 301,500.15		The largest single benefit can be found in replacing the 14 minivans in PWD Monterey’s fleet with PHEVs. Although not an exact substitute, downsizing from a

			minivan to a midsize vehicle results in significant savings and the passenger transport mission of these vehicles is not significantly degraded. Replacing a 7-passenger van with a 5-passenger midsize car may necessitate additional trips due to the low daily mileage and short average trip distances, but will not have an overall negative impact on the replacement. We strongly recommend replacing all minivans in PWD Monterey's fleet with Ford Fusion Energis and making the necessary investment in L1 EVSE to use them in charge depletion mode as much as possible.
Small Pickup Trucks (2WD)	$ (313,717.50)		Small pickup trucks, both 2WD and 4WD, are currently leased under favorable conditions, with an average lease cost of $347 per month. PHEV replacements for these vehicles are up-sized, rather than right-sized, and the new monthly lease cost would more than double the current cost. Irrespective of the small SCC benefit found in replacing a small truck with low mileage with a PHEV truck, the initial cost of infrastructure and the very large increase in the lease cost make replacing this class of vehicles financially a losing proposition.
Small Pickup Trucks (4WD)	$ (38,582.21)		
Standard Pickup Trucks (2WD)	$ (534,964.40)		The largest class we assessed, 2WD standard pickup trucks, is extremely expensive to replace on a monthly and initial infrastructure basis. The largest additional cost is derived from the high market lease price of the replacement vehicle, Via VTRUX. Unless the lease price of the VTRUX is reduced significantly, any advantage that PWD Monterey may observe through SCC benefits will continue to be overwhelmed by the high monthly lease cost.
Cargo Vans	$ (106,118.92)		VIA Vans use the same drive train and lease system as VTRUX and are similarly cost prohibitive. We do not recommend replacing any at this time.

B. SPECIAL CONSIDERATIONS

The following section details eight special considerations that will positively or negatively impact our current replacement model.

1. GSA rates are all-inclusive of fuel and maintenance. If GSA rates did not include fuel, individual vehicle fuel economies would have a larger impact on fuel savings or possible additional costs.

2. Our model and the resulting savings over the term of a vehicle lease are subject to real-world fuel price fluctuations that may change the overall benefit or cost associated with replacing the current fleet with PHEVs. Specifically, lower fuel costs would make replacement less attractive and higher fuel costs would make replacement more attractive.

3. Calculations would differ if PWD Monterey considers buying PHEVs instead of leasing them through GSA. See consideration number 1.

4. Increasing competition in the PHEV market for Cargo vans and all varieties of trucks should increase market supply of these vehicles and drive prices down, making them financially more feasible to purchase or lease.

5. Using the smaller EVSE L1 for midsize vehicles could reduce infrastructure costs enough to make replacing midsize vehicles financially feasible.

6. PHEV technology has improved at an exponential rate. If this continues, it may be possible to realize larger benefits within the next few years.

7. Applying this model to a fleet with larger trip distances or increased daily miles driven would result in ICE usage and decreased SCC benefits.

8. Eliminating or waiving the “Buy American” restriction would allow us to consider multiple other mature PHEVs on the market that may provide additional benefits.

C. FOLLOW-ON RESEARCH

Possibilities for future research are as follows:

1. Determine the feasibility of right-sizing minivans and large cars throughout the entire Navy Region Southwest fleet of approximately 4,000 vehicles.

2. Re-evaluate this model for PWD Monterey using BEVs, FCEVs, and PHEV trucks as these technologies mature or become more readily available and less expensive on the market.

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APPENDIX A. DATA SET

The data set for the non-tactical light duty vehicle fleet at PWD Monterey was provided by NAVFAC's Fleet Transportation Manager, Mr. Bill Dobson, at NSA Monterey. His vehicle logs and files provided the following information:

- License plate number,
- Vehicle year,
- Vehicle make,
- Vehicle model
- Monthly lease rate (to include maintenance and gas) through GSA
- Fuel type
- Vehicle location, and
- Vehicle beginning and ending mileage per month

We averaged out each vehicles monthly mileage to determine the average monthly mileage driven. The collected data is provided in Table 15:

Table 15. PWD Monterey Vehicle Fleet: Collected Data

License Number	Year	Vehicle Make	Vehicle Model	Fuel Type	Monthly Mileage	Monthly Rate (Lease, Maint, Fuel)	Vehicle Location
G10-2908M	2012	Hyundai	Sonata Hybrid	HEV	927.78	$438.40	DLI
G10-2909M	2012	Hyundai	Sonata Hybrid	HEV	202.84	$438.40	Monterey
G10-6639K	2010	Ford	Fusion HEV	HEV	585.02	$438.40	Alameda
G10-6757L	2011	Ford	Fusion HEV	HEV	790.04	$438.40	Treasure Island
G10-6758L	2011	Ford	Fusion HEV	HEV	556.48	$438.40	Monterey
G10-6759L	2011	Ford	Fusion HEV	HEV	192.83	$438.40	Monterey
G10-6760L	2011	Ford	Fusion HEV	HEV	393.27	$438.40	Monterey
G11-0372M	2012	Chevrolet	Impala	UNL/E85	887.35	$971.20	Monterey
G11-2765K	2014	Chevrolet	Impala	UNL/E85	857.58	$971.20	Monterey
G11-3865L	2014	Chevrolet	Impala	UNL/E85	520.96	$971.20	Monterey

License Number	Year	Vehicle Make	Vehicle Model	Fuel Type	Monthly Mileage	Monthly Rate (Lease, Maint, Fuel)	Vehicle Location
G13-0435N	2013	Hyundai	Elantra	UNL	303.89	$369.60	Monterey
G13-0436N	2013	Hyundai	Elantra	UNL	171.14	$369.60	Monterey
G13-5040M	2013	Hyundai	Elantra	UNL	98.94	$369.60	Monterey
G13-5041M	2013	Hyundai	Elantra	UNL	178.26	$369.60	Monterey
G41-0632N	2013	Dodge	Caravan	UNL/E85	393.00	$704.00	Travis
G41-0633N	2013	Dodge	Caravan	UNL/E85	116.43	$704.00	Monterey
G41-0634N	2013	Dodge	Caravan	UNL/E85	326.79	$704.00	Travis
G41-0637N	2013	Dodge	Ram C/V	UNL/E85	173.12	$564.80	Monterey
G41-2306M	2009	Dodge	Grand Caravan	UNL/E85	728.75	$704.00	Monterey
G41-3519K	2010	Dodge	Caravan	UNL/E85	416.69	$704.00	Monterey
G41-3520K	2010	Dodge	Caravan	UNL/E85	712.35	$704.00	Monterey
G41-3521K	2010	Ford	Ranger	UNL	100.78	$347.20	Monterey
G41-3522K	2010	Dodge	Caravan	UNL/E85	486.44	$704.00	Moffett
G41-3555L	2011	Dodge	Caravan	UNL/E85	293.62	$704.00	Monterey
G41-3556L	2011	Ford	Ranger	UNL	973.06	$347.20	Treasure Island
G41-3851P	2014	Dodge	Grand Caravan	UNL/E85	256.67	$704.00	DLI
G41-3935L	2011	Dodge	Dakota	UNL/E85	246.90	$667.20	Travis
G41-3946L	2008	Chevrolet	Uplander	UNL/E85	604.14	$704.80	DLI
G41-4157H	2009	Dodge	Grand Caravan	UNL/E85	620.50	$704.00	Monterey
G41-4158H	2009	Dodge	Grand Caravan	UNL/E85	358.56	$704.00	Monterey
G41-4163H	2009	Ford	Ranger	UNL	473.82	$347.20	Monterey
G41-4164H	2009	Ford	Ranger	UNL	113.79	$347.20	Monterey
G41-4165H	2009	Ford	Ranger	UNL	231.38	$347.20	Monterey
G41-4808P	2014	Dodge	Grand Caravan	UNL/E85	134.62	$704.00	Alameda
G41-4938R	2015	Chevrolet	Colorado	UNL	106.67	$347.20	Monterey
G41-4939R	2015	Chevrolet	Colorado	UNL	271.67	$347.20	Monterey
G41-5483P	2015	Chevrolet	Colorado	UNL	439.33	$347.20	Treasure Island
G41-5484P	2015	Chevrolet	Colorado	UNL	473	$347.20	Alameda
G42-0291B	2008	Chevrolet	Silverado 1500	UNL	194.61	$364.80	Travis
G42-0376M	2012	Ford	Interceptor	UNL	616.54	$1,246.40	Monterey
G42-0705M	2012	Chevrolet	Silverado 1500	UNL	93.25	$364.80	Monterey
G42-1172P	2014	Ford	F-150	UNL/E85	346.41	$364.80	Mare Island
G42-1242F	2007	Chevrolet	Silverado 1500	UNL/E85	307.51	$364.80	Monterey
G42-1249F	2007	Chevrolet	Silverado 1500	UNL/E85	304.03	$364.80	Alameda
G42-1250F	2007	Chevrolet	Silverado 1500	UNL/E85	303.40	$364.80	Travis

License Number	Year	Vehicle Make	Vehicle Model	Fuel Type	Monthly Mileage	Monthly Rate (Lease, Maint, Fuel)	Vehicle Location
G42-1254F	2007	Chevrolet	Silverado 1500	UNL/E85	110.18	$364.80	Monterey
G42-1255F	2007	Chevrolet	Silverado 1500	UNL/E85	218.48	$364.80	Alameda
G42-1260F	2007	Chevrolet	Silverado 1500	UNL/E85	685.06	$364.80	Treasure Island
G42-1305F	2007	Chevrolet	Silverado 1500	UNL/E85	182.78	$364.80	Monterey
G42-1317F	2007	Chevrolet	Silverado 1500	UNL/E85	239.87	$364.80	Alameda
G42-1425R	2015	Chevrolet	Silverado 1500	UNL/E85	297	$364.80	Monterey
G42-1540L	2011	Dodge	Ram 1500	UNL	106.15	$364.80	Monterey
G42-1756K	2010	Chevrolet	Silverado 4X2	UNL	514.37	$364.80	Travis
G43-1185G	2007	Ford	F-250	UNL	278.01	$606.40	Monterey
G43-1839N	2013	Ford	E-350	UNL/E85	138.61	$606.40	Monterey
G43-1840N	2013	Ford	E-350	UNL/E85	201.87	$606.40	Monterey
G43-1841N	2013	Ford	E-350	UNL/E85	370.39	$606.40	Monterey
G43-2008N	2013	Ford	F-250	UNL	194.43	$606.40	Monterey
G43-2009N	2013	Ford	F-250	UNL	99.04	$606.40	Monterey
G43-2010N	2013	Ford	F-250	UNL	190.74	$606.40	Monterey
G43-2011N	2013	Ford	F-250	UNL	119.83	$606.40	Monterey
G43-2012N	2013	Ford	F-250 XL Super Duty	UNL	143.26	$606.40	Monterey
G43-2195F	2007	Ford	E-350 Super Duty	UNL	239.42	$606.40	Monterey
G43-2204F	2007	Ford	E-350 Super Duty	UNL	120.27	$606.40	Monterey
G43-2211F	2007	Ford	E-350 Super Duty	UNL	219.33	$606.40	Monterey
G43-2228F	2007	Chevrolet	Silverado 2500	UNL	161.50	$606.40	Monterey
G43-2271M	2012	Ford	F-250 Super Duty	UNL	159.25	$606.40	Monterey
G43-2272M	2012	Ford	F-250 Super Duty	UNL	80.25	$606.40	Monterey
G43-2274M	2012	Ford	F-250 Super Duty	UNL	162.94	$606.40	Monterey
G43-2285R	2015	Ford	F-350 Dually	UNL	436.20	$606.40	Monterey
G43-2440K	2010	Ford	E-150	UNL/E85	333.25	$564.80	Monterey
G43-2802H	2009	Chevrolet	C2500 HD	UNL	151.52	$606.40	Monterey
G43-2803H	2009	Chevrolet	C2500 HD	UNL	172.32	$606.40	Monterey
G43-2804H	2009	Chevrolet	3500 HD	UNL	80.41	$606.40	Monterey
G43-2846K	2011	Ford	F-250 Super Duty	UNL	178.73	$606.40	Monterey
G43-2847K	2011	Ford	F-250 Super Duty	UNL	121.37	$606.40	Monterey
G43-2848K	2011	Ford	F-250 Super Duty	UNL	189.66	$606.40	Monterey
G43-2849K	2010	Chevrolet	Silverado 2500 HD	UNL	156.40	$606.40	Monterey
G43-2850K	2010	Chevrolet	Silverado 2500 HD	UNL	306.37	$606.40	Monterey
G43-2851K	2011	Ford	F-250 Super Duty	UNL	186.78	$606.40	Monterey

License Number	Year	Vehicle Make	Vehicle Model	Fuel Type	Monthly Mileage	Monthly Rate (Lease, Maint, Fuel)	Vehicle Location
G43-2852K	2011	Ford	F-250 Super Duty	UNL	254.56	$606.40	Monterey
G43-3261R	2015	Chevrolet	2500 HD Silverado	UNL/E85	472	$606.40	Treasure Island
G43-3589F	2014	Chevrolet	Silverado	UNL	601.29	$667.20	Monterey
G61-1282R	2015	Chevrolet	Colorado	UNL	802	$347.20	Treasure Island
G62-3204L	2011	Dodge	Ram 1500	UNL	247.97	$364.80	Monterey
G63-1413R	2015	Chevrolet	K3500 4X4	UNL	597	$731.20	Monterey
G63-1730L	2011	Dodge	Ram 2500 4x4	UNL	232.92	$731.20	Monterey

Based on the list of vehicles provided, we used the www.fueleconomy.gov website to determine each vehicles EPA classification and combined miles per gallon (MPG) (U.S. Department of Energy, 2015). After determining the combined MPG, we divided the combined MPG by the amount of CO_2 emitted from a gallon of gasoline (8,887 grams CO_2/gallon) to calculate the amount of carbon emitted by each vehicle in this study (Office of Transportation and Air Quality, 2014).

APPENDIX B: NET PRESENT VALUE TABLES

This appendix shows the tabulated calculations for each EPA classification, in order to fully represent the costs, benefits and valuation of each class's transition. The net present value worksheets displayed in this Appendix (Tables 16–22) calculate costs and benefits on an annual basis.

Table 16. Large Cars

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	0	1	2	3	4	5	6	7
Discount Rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
COSTS (INPUTS) in $								
Infrastructure Costs	$ 2,937.90	$ -	$ -	$ -	$ -	$ -	$ -	$ -
DISCOUNTED TOTAL COSTS	$ 2,937.90	$ -	$ -	$ -	$ -	$ -	$ -	$ -
BENEFITS (OUTCOMES) in $								
Average Annual SC-CO2 Savings	$ 642.85	$ 642.85	$ 642.85	$ 642.85	$ 642.85	$ 642.85	$ 642.85	$ 642.85
Vehicle Lease Savings	$ 1,466.28	$ 1,466.28	$ 1,466.28	$ 1,466.28	$ 1,466.28	$ 1,466.28	$ 1,466.28	$ 1,466.28
DISCOUNTED TOTAL BENEFITS	$ 2,109.13	$ 1,971.15	$ 1,842.20	$ 1,721.68	$ 1,609.05	$ 1,503.78	$ 1,405.40	$ 1,313.46
NET BENEFITS	**$ (828.77)**	**$ 1,971.15**	**$ 1,842.20**	**$ 1,721.68**	**$ 1,609.05**	**$ 1,503.78**	**$ 1,405.40**	**$ 1,313.46**
Large Car Lifetime Costs	$ 2,937.90							
Large Car Lifetime Benefits	$ 13,475.84							
Sum of Net Benefits over 7 yrs:	**$ 10,537.94**							

Table 17. Midsize Cars

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	0	1	2	3	4	5	6	7
Discount Rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
COSTS (INPUTS) in $								
Infrastructure Costs	$ 23,050.70	$ -	$ -	$ -	$ -	$ -	$ -	$ -
DISCOUNTED TOTAL COSTS	$ 23,050.70	$ -	$ -	$ -	$ -	$ -	$ -	$ -
BENEFITS (OUTCOMES) in $								
Average Annual SC-CO2 Savings	$ 584.02	$ 584.02	$ 584.02	$ 584.02	$ 584.02	$ 584.02	$ 584.02	$ 584.02
Vehicle Lease Savings	$ 2,699.40	$ 2,699.40	$ 2,699.40	$ 2,699.40	$ 2,699.40	$ 2,699.40	$ 2,699.40	$ 2,699.40
DISCOUNTED TOTAL BENEFITS	$ 3,283.42	$ 3,068.62	$ 2,867.87	$ 2,680.25	$ 2,504.91	$ 2,341.03	$ 2,187.88	$ 2,044.75
NET BENEFITS	**$ (19,767.28)**	**$ 3,068.62**	**$ 2,867.87**	**$ 2,680.25**	**$ 2,504.91**	**$ 2,341.03**	**$ 2,187.88**	**$ 2,044.75**
Midsize Car Lifetime Costs	$ 23,050.70							
Midsize Car Lifetime Benefits	$ 20,978.72							
Sum of Net Benefits over 7 yrs:	**$ (2,071.98)**							

Table 18. Minivans

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	0	1	2	3	4	5	6	7
Discount Rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
COSTS (INPUTS) in $								
Infrastructure Costs	$ 13,710.20	$ -	$ -	$ -	$ -	$ -	$ -	$ -
DISCOUNTED TOTAL COSTS	$ 13,710.20	$ -	$ -	$ -	$ -	$ -	$ -	$ -
BENEFITS (OUTCOMES) in $								
Average Annual SC-CO2 Savings	$ 1,869.14	$ 1,869.14	$ 1,869.14	$ 1,869.14	$ 1,869.14	$ 1,869.14	$ 1,869.14	$ 1,869.14
Vehicle Lease Savings	$ 47,465.04	$ 47,465.04	$ 47,465.04	$ 47,465.04	$ 47,465.04	$ 47,465.04	$ 47,465.04	$ 47,465.04
DISCOUNTED TOTAL BENEFITS	$ 49,334.18	$ 46,106.71	$ 43,090.38	$ 40,271.39	$ 37,636.81	$ 35,174.59	$ 32,873.45	$ 30,722.85
NET BENEFITS	**$ 35,623.98**	**$ 46,106.71**	**$ 43,090.38**	**$ 40,271.39**	**$ 37,636.81**	**$ 35,174.59**	**$ 32,873.45**	**$ 30,722.85**
Minivans Lifetime Costs	$ 13,710.20							
Minivans Lifetime Benefits	$ 315,210.35							
Sum of Net Benefits over 7 yrs:	**$ 301,500.15**							

Table 19. Small Pickup Trucks (2WD)

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	0	1	2	3	4	5	6	7
Discount Rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
COSTS (INPUTS) in $								
Infrastructure Costs	$ 18,591.30							
Vehicle Lease Costs	$ 47,291.04	$ 47,291.04	$ 47,291.04	$ 47,291.04	$ 47,291.04	$ 47,291.04	$ 47,291.04	$ 47,291.04
DISCOUNTED TOTAL COSTS	$ 65,882.34	$ 44,197.23	$ 41,305.83	$ 38,603.58	$ 36,078.11	$ 33,717.86	$ 31,512.02	$ 29,450.48
BENEFITS (OUTCOMES) in $								
Average Annual SC-CO2 Savings	$ 1,100.27	$ 1,100.27	$ 1,100.27	$ 1,100.27	$ 1,100.27	$ 1,100.27	$ 1,100.27	$ 1,100.27
DISCOUNTED TOTAL BENEFITS	$ 1,100.27	$ 1,028.29	$ 961.02	$ 898.15	$ 839.39	$ 784.48	$ 733.16	$ 685.19
NET BENEFITS	**$ (64,782.07)**	**$ (43,168.94)**	**$ (40,344.81)**	**$ (37,705.43)**	**$ (35,238.72)**	**$ (32,933.38)**	**$ (30,778.86)**	**$ (28,765.29)**
Small Pickup Trucks (2WD) Lifetime Costs	$ 320,747.44							
Small Pickup Trucks (2WD) Lifetime Benefits	$ 7,029.94							
Sum of Net Benefits over 7 yrs:	$ (313,717.50)							

Table 20. Small Pickup Trucks (4WD)

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	0	1	2	3	4	5	6	7
Discount Rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
COSTS (INPUTS) in $								
Infrastructure Costs	$ 2,065.70							
Vehicle Lease Costs	$ 6,023.64	$ 6,023.64	$ 6,023.64	$ 6,023.64	$ 6,023.64	$ 6,023.64	$ 6,023.64	$ 6,023.64
DISCOUNTED TOTAL COSTS	$ 8,089.34	$ 5,629.57	$ 5,261.28	$ 4,917.08	$ 4,595.41	$ 4,294.77	$ 4,013.81	$ 3,751.22
BENEFITS (OUTCOMES) in $								
Average Annual SC-CO2 Savings	$ 308.37	$ 308.37	$ 308.37	$ 308.37	$ 308.37	$ 308.37	$ 308.37	$ 308.37
DISCOUNTED TOTAL BENEFITS	$ 308.37	$ 288.20	$ 269.34	$ 251.72	$ 235.25	$ 219.86	$ 205.48	$ 192.04
NET BENEFITS	**$ (7,780.97)**	**$ (5,341.37)**	**$ (4,991.94)**	**$ (4,665.36)**	**$ (4,360.15)**	**$ (4,074.91)**	**$ (3,808.33)**	**$ (3,559.18)**
Small Pickup Trucks (4WD) Lifetime Costs	$ 40,552.48							
Small Pickup Trucks (4WD) Lifetime Benefits	$ 1,970.27							
Sum of Net Benefits over 7 yrs:	$ (38,582.21)							

Table 21. Standard Pickup Trucks

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	0	1	2	3	4	5	6	7
Discount Rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
COSTS (INPUTS) in $								
Infrastructure Costs	$ 35,444.90							
Vehicle Lease Costs	$ 80,055.72	$ 80,055.72	$ 80,055.72	$ 80,055.72	$ 80,055.72	$ 80,055.72	$ 80,055.72	$ 80,055.72
DISCOUNTED TOTAL COSTS	$ 115,500.62	$ 74,818.43	$ 69,923.77	$ 65,349.31	$ 61,074.13	$ 57,078.62	$ 53,344.51	$ 49,854.68
BENEFITS (OUTCOMES) in $								
Average Annual SC-CO2 Savings	$ 1,874.96	$ 1,874.96	$ 1,874.96	$ 1,874.96	$ 1,874.96	$ 1,874.96	$ 1,874.96	$ 1,874.96
DISCOUNTED TOTAL BENEFITS	$ 1,874.96	$ 1,752.30	$ 1,637.66	$ 1,530.53	$ 1,430.40	$ 1,336.82	$ 1,249.37	$ 1,167.63
NET BENEFITS	**$ (113,625.66)**	**$ (73,066.13)**	**$ (68,286.10)**	**$ (63,818.79)**	**$ (59,643.73)**	**$ (55,741.80)**	**$ (52,095.14)**	**$ (48,687.05)**
Standard Pickup Trucks (2WD) Lifetime Costs	$ 546,944.06							
Standard Pickup Trucks (2WD) Lifetime Benefits	$ 11,979.66							
Sum of Net Benefits over 7 yrs:	$ (534,964.40)							

Table 22. Cargo Vans

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
	0	1	2	3	4	5	6	7
Discount Rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
COSTS (INPUTS) in $								
Infrastructure Costs	$ 14,459.90							
Vehicle Lease Costs	$ 15,089.76	$ 15,089.76	$ 15,089.76	$ 15,089.76	$ 15,089.76	$ 15,089.76	$ 15,089.76	$ 15,089.76
DISCOUNTED TOTAL COSTS	$ 29,549.66	$ 14,102.58	$ 13,179.98	$ 12,317.74	$ 11,511.91	$ 10,758.79	$ 10,054.94	$ 9,397.14
BENEFITS (OUTCOMES) in $								
Average Annual SC-CO2 Savings	$ 744.03	$ 744.03	$ 744.03	$ 744.03	$ 744.03	$ 744.03	$ 744.03	$ 744.03
DISCOUNTED TOTAL BENEFITS	$ 744.03	$ 695.36	$ 649.86	$ 607.35	$ 567.62	$ 530.48	$ 495.78	$ 463.34
NET BENEFITS	**$ (28,805.63)**	**$ (13,407.22)**	**$ (12,530.12)**	**$ (11,710.39)**	**$ (10,944.29)**	**$ (10,228.31)**	**$ (9,559.17)**	**$ (8,933.80)**
Cargo Vans Lifetime Costs	$ 110,872.74							
Cargo Vans Lifetime Benefits	$ 4,753.82							
Sum of Net Benefits over 7 yrs:	$ (106,118.92)							

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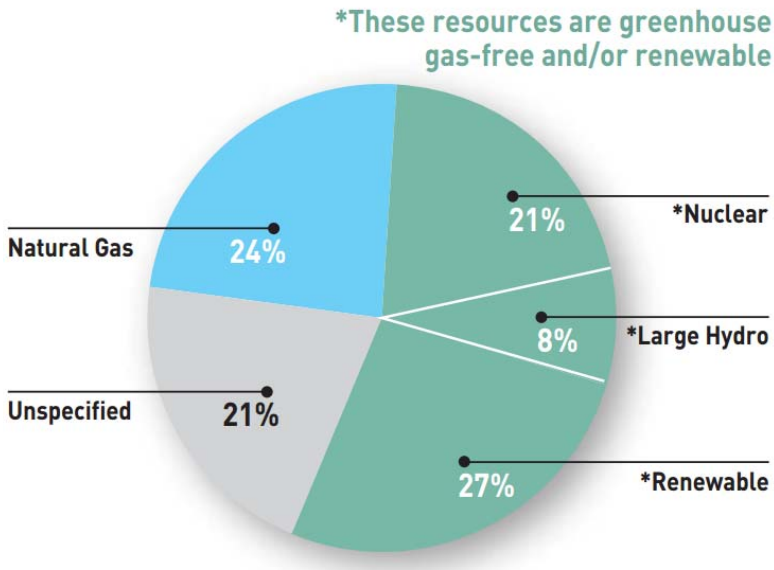
APPENDIX C: PG&E ELECTRIC GRID SOURCES AND ASSUMPTIONS

In order to calculate the SCC within power provided by the PG&E electric grid, we utilized *PG&E's 2014 Power Mix* to gain an initial quantitative idea of the electric source breakdown. According to the report, sources which contributed to the electric grid used in Central California in 2014 are shown in Figure 23.

Figure 23. PG&E 2014 Power Mix



Source: Pacific Gas and Electric. (2015b). PG&E's 2014 power mix. San Francisco: Pacific Gas and Electric. Retrieved from http://www.pge.com/includes/docs/pdfs/myhome/myaccount/explanationofbill/billinserts/11.15_PowerContent.pdf

The "unspecified" component of the mix is electricity purchased by PG&E that cannot be traced to specific generation sources. In order to resolve this large "unspecified" section in our model, we used the EIA's calculation of U.S. energy sources and their respective share of the overall national electricity generation for 2014, broken down in Figure 24.

Figure 24. U.S. Energy Sources by Type

- Coal = 39%
- Natural gas = 27%
- Nuclear = 19%
- Hydropower = 6%
- Other renewables = 7%
  - Biomass = 1.7%
  - Geothermal = 0.4%
  - Solar = 0.4%
  - Wind = 4.4%
- Petroleum = 1%
- Other gases < 1%

Source: *FAQ: What is U.S. electricity generation by energy source.* (2015, March 31). Retrieved December 2, 2015, from U.S. Energy Information Administration Web site: https://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3

We understand that coal is subcategorized into bituminous, sub-bituminous, anthracite and lignite and that these different types of coal release significantly different amounts of carbon dioxide into the atmosphere when burned. The EIA developed an Annual Coal Report for 2013 (released in 2015) that displays the percentage of coal produced in the U.S. by type. The U.S. coal production breakdown in the EIA report, by percentage of each type of coal, is: Bituminous 47.8%, Sub-bituminous 44.1%, Lignite 7.8%, and Anthracite 0.2% (Annual coal report, 2015).

In order to determine the SCC, we used an EIA developed chart that details the number of pounds of carbon dioxide produced when producing a kWh of electricity from a variety of different non-renewable fuel sources, displayed as Figure 25.

Figure 25. Carbon Dioxide Generation per kWh for Non-renewable Fuel Sources

Fuel	Pounds of CO2 per Million Btu	Heat rate (Btu per kWh)	Pounds of CO2 per kWh
Coal			
Bituminous	205.300	10,089	2.07
Sub-bituminous	212.700	10,089	2.15
Lignite	215.400	10,089	2.17
Natural gas	117.080	10,354	1.21
Distillate oil (No. 2)	161.386	10,334	1.67
Residual oil (No. 6)	173.906	10,334	1.80

Source: FAQ: How much carbon dioxide is produced per kilowatt hour when generating electricity with fossil fuels? (2015, March 30). Retrieved from U.S. Energy Information Administration Web site: https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

At this point we applied the U.S. national average of electricity sources to the "unspecified" component of the PG&E model, and applied the appropriate coal mix given by the EIA to attain a detailed model of the carbon emissions produced by PG&E "unspecified" sources. We further assumed that national averages for petroleum are comprised of half Distillate oil (No.2) and half Residual oil (No. 6) from Figure 25. Our conclusion from this portion of our analysis is that a kWh generated by PG&E "unspecified" sources generates 1.1607 pounds of carbon dioxide, displayed in Table 23.

Table 23. PG&E “Unspecified” Source CO2 Produced per kWh

"Unspecified" Breakdown				
Source Type		**Breakdown**	**lbs CO2 per kWh**	**Actual lbs CO2 per kWh**
Coal	39.00%			
Lignite	7.00%	2.73%	2.17	0.0592
Bituminous	45.00%	17.55%	2.07	0.3633
Sub-Bituminous	47.00%	18.33%	2.15	0.3941
Natural Gas		27.00%	1.21	0.3267
Petroleum		1.00%	1.74	0.0174
Greenhouse Gas Producing Total		**66.61%**		
Nuclear		19.00%	0.00	0.0000
Hydropower		6.00%	0.00	0.0000
Biomass		1.70%	0.00	0.0000
Geothermal		0.40%	0.00	0.0000
Solar		0.40%	0.00	0.0000
Wind		4.40%	0.00	0.0000
Greenhouse Gas Free Total		**31.90%**		
Grand Total		**98.51%**		**1.1607**

Finally, we took *PG&E’s 2014 Power Mix* to create a number of grams of carbon dioxide generated per mile driven by our PHEVs. From the Power Mix, 56% of the electricity sources are greenhouse gas-free, 24% of the electricity comes from Natural Gas, and 21% comes from the previously mentioned “unspecified” sources. We then took the carbon dioxide produced per kWh of Natural Gas from Figure 25, and the carbon dioxide produced per kWh from “unspecified” sources from Table 23 and applied them to the manufacturer-given PHEV electric consumption per mile ratios to determine carbon emissions from the grid per mile driven by a PHEV. An example formulation for a PHEV is shown in Table 24.

Table 24. Chevrolet Volt CO2 Produced per Mile Driven

Example C1: Chevrolet Volt CO2 Produced per Mile Driven						
PG&E Power Mix 2014	**Percentage**	**lbs CO2 per kWh Constant**	**Actual lbs CO2 per mile**	**Volt kWh/mile**	**lbs CO2/mile**	**g CO2/mile**
Greenhouse Gas Free	56%	0.0000	0	0.45	0	0
Natural Gas	24%	1.2100	0.2094	0.45	0.094230	42.74
"Unspecified"	21%	1.1607	0.2437	0.45	0.109686	49.75
Total*	**101%**		**0.5341**	0.45	**0.240366**	**109.03**

One example vehicle in the PWD Monterey fleet that would be replaced with a Chevrolet Volt travels 11,143.41 miles annually. At 109.03 grams of carbon dioxide generated per mile shown in Table 24 and using the constant of 1,000,000 grams in a metric ton, the Chevrolet Volt replacing the selected vehicle will produce 1.215 metric tons of carbon dioxide annually. Using the EPA generated 2015 SCC 3% discount rate of $40 per metric ton, the Chevrolet Volt will generate a SCC of $48.60 in 2015.

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